SURGERY
of
PERIPHERAL NERVES

By

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INTRODUCTION

n civilian practice there is rarely adequate terial available to any one man or any up of men for extensive study of periph- [nerve problems. All the outstanding nciples have been founded for the most t on animal experimentation in the lab- tory

Thanks to the excellent policy of the geon General s Office, and the persistent d untiring interest of R. Glen Spurling and nes Woodhall it has been possible to re- r and follow up the vast number of cases nerve injuries, which were incurred in orld War II, to complete recovery As a ult many important principles were rned.

During an extended period of service at akeman Hospital Center, we personally served repaired and followed the prog- s of 2037 peripheral nerve injuries. The majority of these were followed to the point of maximum recovery This was possible be- cause the four to five thousand bed con- valescent hospital was a part of the hospital center

On analyzing our fortunate results we de- cided that they were largely due to the new and original variations in technique de- veloped in our service

I am most grateful to Colonel H S Con- ner, Commanding Officer, Lieutenant Colo- nel Caleb S Stone Jr , Colonel Truman Blocker, Lieutenant Colonel A. McCravey, and Lieutenant Colonel Sam Banks not only for their insistence that we record our re- sults in this volume but especially for per- mitting me to innovate original procedures and for encouraging the cooperation among our departments in behalf of this work.

EMIL SELETZ

Los Angeles, California

ACKNOWLEDGMENTS

In the accomplishment of this work I owe warm thanks to many for their help and loyalty beyond the line of duty

First of all I wish to acknowledge my gratitude to Dr Barnes Woodhall for the inspiration which his advice and suggestions afforded me during his visit to our hospital while he was in charge of Neurological Surgery in the United States.

To my sister Dr Rachelle Seletz, I humbly give credit for reading and correcting the galley proofs as well as for assisting me in planning the entire text.

Major credit goes to Jean McConnell for the beautiful anatomical drawings, the result of many weeks of patient labor at the post, sketching in the operating room.

To Tom Jones Professor of Medical Illustration at the University of Illinois goes my warmest appreciation for his indispensable guidance and direction at the outset of my task.

I acknowledge great indebtedness to the Department of Anatomy of the University of Illinois for graciously allowing me the use of the Anatomy Laboratory

I wish to thank Sgt Buck, E. J Hoffman and Carl Emory for the excellent photographs and Sgt. Earl Tucker, the N C.O , for his zeal and tireless efforts in my behalf, during my stay at the post.

I owe a particular debt of gratitude to my Secretary, Miss Mary Elizabeth McDonald, for her sincere interest, efficiency and loyalty

To Dr Caleb Stone Jr of Seattle, Washington, the Chief of our Surgical Service, the author wishes to express warmest gratitude, for it was his suggestion that gave birth to this book. It was a rare privilege to be associated with and under the guidance of so rare a gentleman

And finally I ask that my publisher, Charles C Thomas, accept my heartfelt appreciation and friendship for his encouragement and advice at all times

EMIL SELETZ

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PERIPHERAL NERVES

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I

PRINCIPLES AND TECHNIQUE OF NERVE SURGERY

ANATOMICAL CONSIDERATIONS

All the major nerve trunks lie deep, in proximity to major blood vessels, therefore proper exposure is an important factor in surgical technique

In using the longitudinal incisions, it was considered justifiable to continue the incision even across flexion creases in order to obtain proper exposure Following through our extensive series of convalescent patients, we were impressed by the vast number of deformities and contracture scars following elective extremity surgery Careful evaluation of these scars revealed that these deformities were produced when the incisions had been carried across joints and perpendicular to flexion creases. From these observations we concluded that the skin incisions must be planned so as not to cross a flexion crease

Correct and incorrect (old and new) incisions are illustrated in Figs. 1–11 The new and modified incisions and new surgical approaches presented in this monograph are based on the surgery and study of 2 037 peripheral nerve lesions. These new procedures were first introduced in a preliminary report in 1945 and are now presented in detail.

The drawings of the surgical exposures were made in the operating room at the time of surgery

The incisions of the extremities have for the most part been divided into three parts. This is especially true for incisions about the cubital and popliteal fossae One part alone is usually sufficient for repair of the nerve, while two or all three parts may be used when re routing as well as when repair is necessary (Figs 12–15)

Figs. 16 and 17 show the advantage of the transclavicular approach to the brachial plexus over the method in which resection of the clavicle is used

In devising the new incisions, adherence to the following surgical principles was found to be of utmost importance

1 Adequate exposure of the injured nerve
2 The approach to deeply lying nerves is made through fascial planes, rather than by penetrating through muscle substance
3 If a muscle must be penetrated, it is always split in the direction of its fibers.
4 When a muscle must be divided, it is severed only at its point of fascial attachment so that it may be easily repaired
5 Maiming operations, such as shortening of a normal long bone, or resection of a clavicle, are avoided when possible (Figs. 16 and 17)
6 Skin incisions that are perpendicular to flexion creases *must be avoided*, since a traction scar will invariably result Not only is the skin involved in the production of traction scars but subcutaneous tissues and fascial layers as well (Figs 2 4 6 7)



Figure 1 Correct incision. An infraclavicular incision for the exposure of the brachial plexus beneath the pectoralis major muscles.

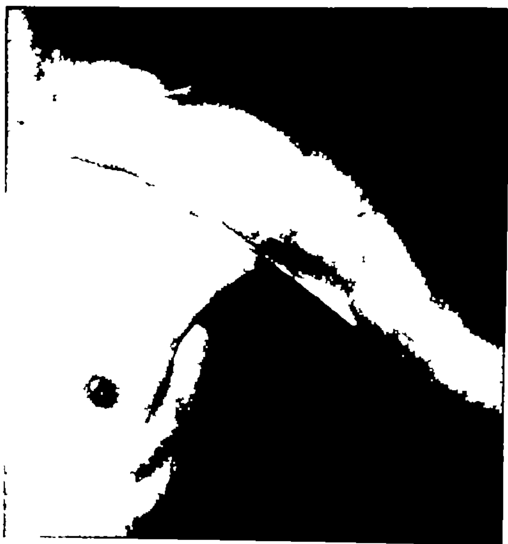


Figure 2 Incorrect incision. A traction scar resulting from an erroneously planned infraclavicular incision crossing the anterior axillary fold.



Figure 1 Correct Incision. An infraclavicular incision for the exposure of the brachial plexus beneath the pectoralis major muscles.



Figure 2 *Incorrect incision.* A traction scar resulting from an erroneously planned infraclavicular incision crossing the anterior axillary fold



Figure 3 Correct incision. A transverse axillary incision for the exploration of the brachial plexus.



Figure 4 Incorrect incision. A traction scar resulting from an incision perpendicular to the flexion crease at the axilla.



Figure 5 Correct incision. The author's Z-shaped incision of the arm and cubital space (post-operative) Through this incision, re-routing and neurorrhaphy of the median nerve was performed

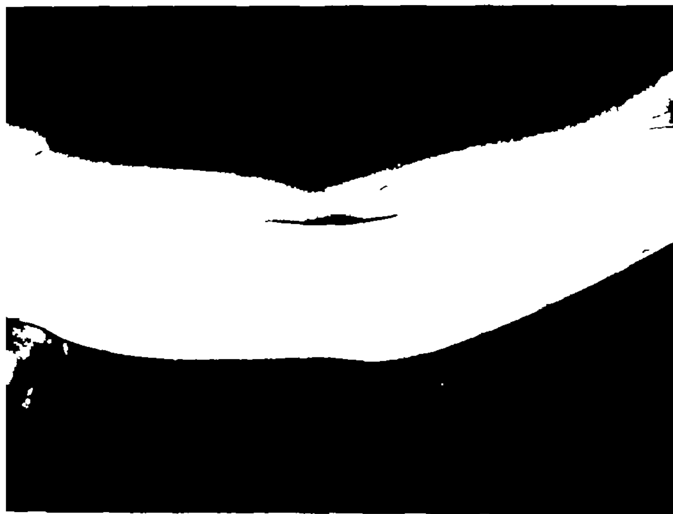


Figure 6. Incorrect incision. A traction scar resulting from an incision perpendicular to the flexion crease at the cubital fossa following a median nerve repair

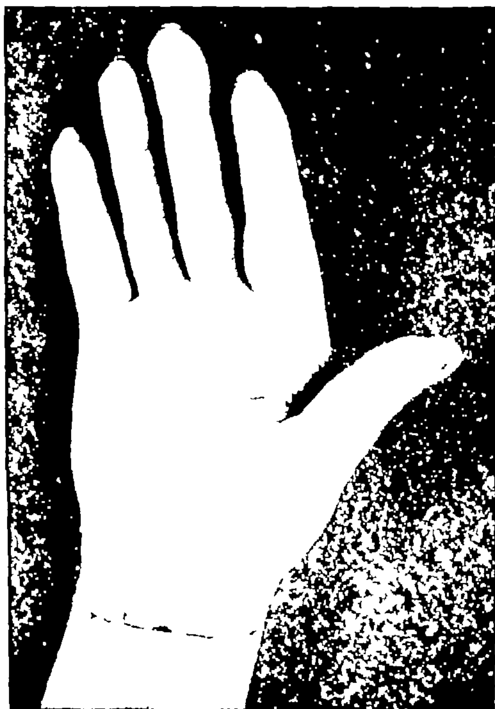


Figure 7 Correct Incision. A transverse incision for exposure of the median and ulnar nerves at the wrist.

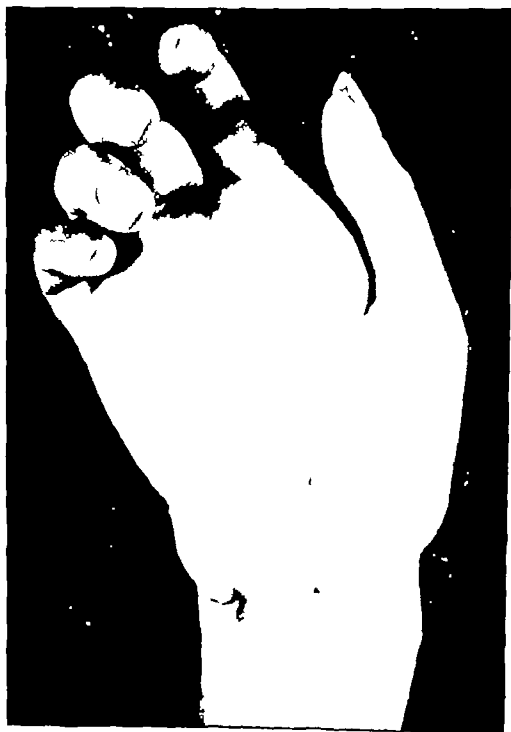


Figure 8 Incorrect incision. Traction scars resulting from incisions perpendicular to the flexion crease at the wrist.



Figure 9 Correct incision. A combined incision for exposing the median nerve in the forearm and in the hand.

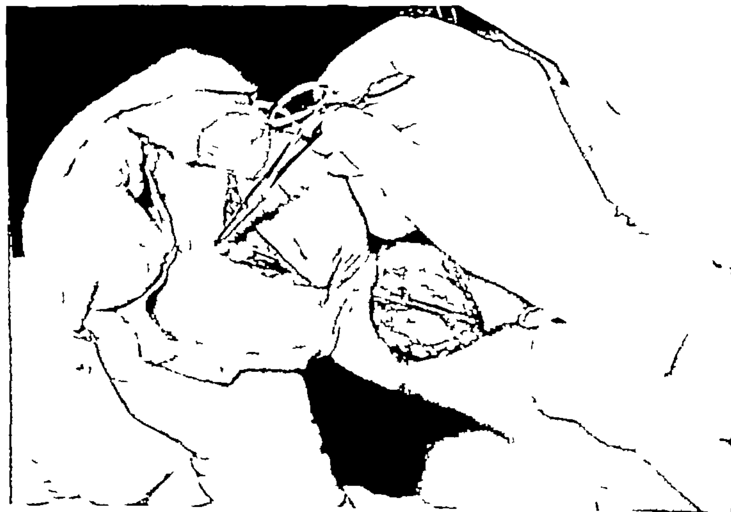


Figure 10. Correct incision. The incision shown in Figure nine with the wound open.



Figure 11 An incision following a flexion crease in the popliteal space for exposure of the tibial nerve



Figure 12 An incision for exploration and re-routing of the median nerve in the arm and forearm.



Figure 13 An exposure of the median nerve and blood vessels in the arm and forearm by use of the combined incision as shown in Figure 11 The median nerve is elevated by the instrument.

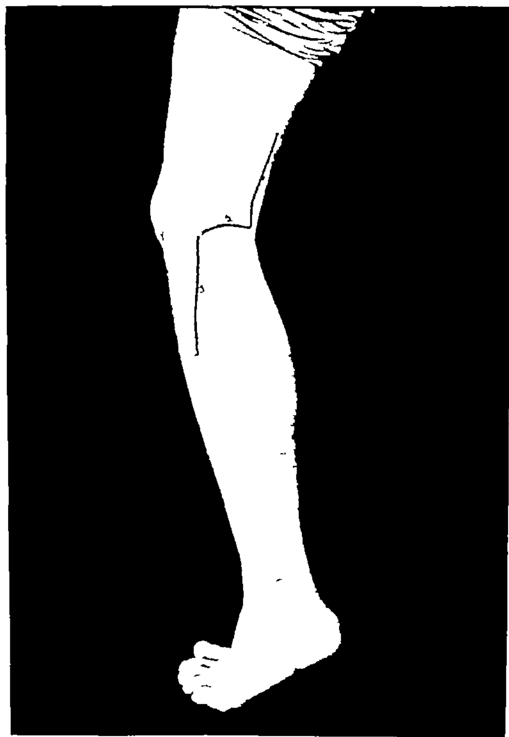


Figure 14 An incision for exploring the tibial, and peroneal nerves in the region of the popliteal fossa.



Figure 15 Operative exposure of the incision shown in Figure 14 There is seen the sciatic nerve with it division into the tibial and peroneal nerves in the popliteal region.

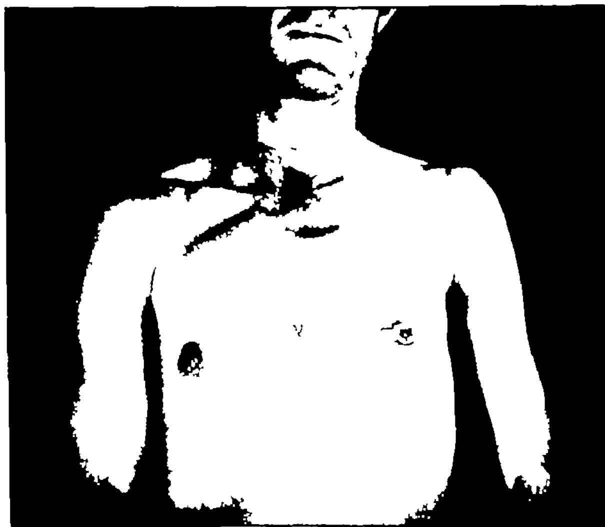


Figure 16 A deformity of the clavicle often results when following a subperiosteal resection of the clavicle in brachial plexus exposure.



Figure 17. A transclavicular approach (post-operative). The integrity of the clavicle is maintained when transclavicular approach is used for a brachial plexus exposure.

TIME OF NERVE REPAIR

Nerve repair may be performed immediately, when lacerations of soft tissues are accompanied by injuries to peripheral nerves, providing the injury is not associated with extensive loss of nerve substance[1] Primary skin closure is always preferred in these cases. When it is found necessary to pack the wound or insert a drain the nerve should be approximated with a few sutures to prevent additional retraction of the nerve ends and to enable nerves to be more easily found at subsequent procedures Mildly infected wounds may be closed by secondary suture as soon as a granulating surface is reasonably clean.[2] Nerve repair may be attempted within three weeks after secondary closure, if infection has subsided The delay of nerve repair of from four to six months has now been abandoned Nerve healing will result in most instances, even when wound infection is present.[3] In recent experimental studies, Davis has shown that a peripheral nerve is more resistant to infection than are the muscles, tendons, fat or fasciae[4]

CHEMOTHERAPY

Sulfadiazine, given one gram by mouth every four hours for three days combined with twenty to thirty thousand units of penicillin every four hours for three days following surgery is a most satisfactory method of preventing infection in a potentially contaminated wound This was carried out in a series of over seven hundred consecutive nerve repairs at Wakeman General Hospital without a single serious wound infection[5] Sulfadiazine, given by mouth in above dosage, has been much more effective than a local application in clearing up, as well as in preventing, infection Wet dressings of concentrated penicillin to an infected wound, however, have been very effective.

FROZEN SECTION NEUROMA EXAMINATION

Vital staining and frozen section technique of neuroma examination of Antopol[6] is the only sure way of removing neuroma and scar tissue from both the central and peripheral ends of severed nerves. Results of a series of over eight hundred nerve repairs in which this was performed testify to the excellence of this procedure[7]

TECHNIQUE OF NERVE SUTURE

Accurate approximation of the epineurium with interrupted sutures of silk after complete removal of scar and neuromatous tissue is the method of choice in nerve repair The author does not favor any of the sutureless techniques since they will not hold in the presence of excessive tension Tantalum foil cuffs or other cuffs are believed to act deleteriously by preventing the nerve sheath from contact with adjacent viable tissues and tissue juices[8] To quote Loyal Davis, 'The ideal surgical method of repairing a peripheral nerve injury is an end to-end apposition of the divided ends at the earliest possible moment following division with the

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[1] Scarff J E. The surgical treatment of injuries of the brain, spinal cord and peripheral nerves. Surg Gynec & Obst., 405–424 1945

[2] Spurling, R. G.: Peripheral nerve surgery technical consideration. J Neurosurg 1 133–148 1944.

[3] Davis, L.: Peripheral nerve surgery Surg Gynec & Obst., 80 444–446

[4] Davis, L., Perret G and Hiller F Experimental studies in peripheral nerve surgery IV The effect of infection of regeneration and functional recovery Surg Gy & Ob 8 10 3 8 1945

[5] Unpublished data.

[6] Antopol, Wm Frozen section neuroma examination Vital staining technique Personal communication to the author

[7] Paper in preparation.

[8] Barnell, S. Personal communication to the author



Figure 17 A transclavicular approach (post-operative) The integrity of the clavicle is maintained when transclavicular approach is used for a brachial plexus exposure.

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[6] Antopol, Wm. Frozen section neuroma examination Vital staining technique Personal communication to the author

[7] Paper in preparation.

[8] Bunnell S Personal communication to the author

finest possible suture material which passes through the epineurium of the nerve trunk While it is of paramount importance to use as fine a suture material as possible, yet it has been found unwise when dealing with nerves under great tension to use suture material so fine that it will break or cut the sheath.

SLING STITCH TRANSFIXION SUTURE

A sling stitch or transfixion suture should never be used. The only excuse for this type of suture is when apposition of the nerve ends is impossible without it. Tantallum sutures are difficult to handle time consuming and have a tendency to cut through the sheath when under tension. However excellent results with the use of tantallum sutures have been observed

RETENTION SUTURE (TRACTION SUTURE)

In order to relieve tension at the site of nerve repair a well planned traction suture is placed through the epineurium only and anchored to some fixed area adjacent to the nerve

SHEATH DISTENSION AND FIBRIL ALIGNMENT

Following the suture of a divided nerve one or more cubic centimeters of normal saline, or preferably one per cent novocaine is instilled intra-neurally into the central end about one centimeter from the point of nerve suture and directed toward the peripheral end The sheath at the point of suture is distended, any projecting fibrils are directed inside the sheath and all the fibrils are aligned in the proper direction (Fig 18)

ANESTHESIA

Local anesthesia is the anesthetic of choice for all peripheral nerve repair Since many of these repairs entail extensive exploration and re routing use of local anesthesia avoids the unnecessary risk of long protracted general anesthetics These patients are ambulatory and may have regular diet within twenty four hours. Local anesthesia necessarily presupposes more careful handling of all tissues, especially the nerves. In a series of over one thousand peripheral nerves repaired all but eight were performed under local anesthesia. Electrical tests on the exposed nerves may best be carried out with the patient awake and cooperative Only under local anesthesia does one learn to have proper respect for tissues. Local infiltration also serves the excellent functions of tissue and layer separation and of hemostasis.

USE OF TOURNIQUET

The author agrees with Spurling that a tourniquet need never be used in peripheral nerve repair A clean dry field and most satisfactory circumstances can only be obtained by avoiding the temporary dry field and possibly injurious constricting effect of a tourniquet.[9] [10]

[9] Speigel, J L and Lewin P.: Tourniquet paralysis. Analysis of three cases f surgically proved peripheral nerve damage following use of rubber tourniquet. *J.A.M.A.*, 1 9.43 -435 945

[10] Denny Brown and Brenner C.: Paralysis f nerve by induced, direct pressure and by tourniquet. *Arch. Neurol. & Psychiat* 5111- 6, 1944.

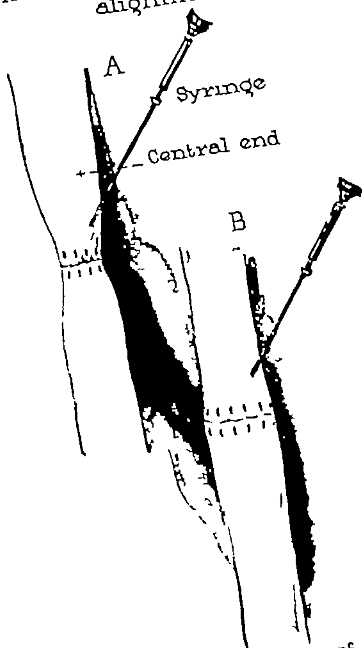

Sheath distension and fibril alignment
A
Syringe
Central end
B
After injection of normal saline or 1% novocaine

Figure 18

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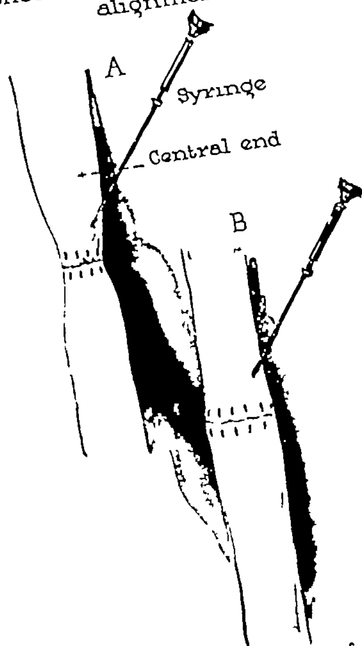

Sheath distension and fibril alignment
A
Syringe
Central end
B
After injection of normal saline or 1% novocaine

Figure 18

ELECTRICAL TESTS OF THE EXPOSED NERVE

Electrical stimulation of the exposed nerve is of value in questionable cases and in incomplete nerve injuries. It is also of value in outlining the extent of a "neuroma in continuity" involving only a portion of the nerve. It has been successful in selecting the sensory fibrils in treatment of certain cases of causalgia, "selective fibril section." Electrical stimulation is of definite value in determining the physiological continuity of a nerve.

COMBINED INJURIES

When bone and nerve lesions co-exist the nerve lesion is of primary consideration and its repair must take precedence for the following reasons:

1. Bone is of value only when it serves for attachment of normal muscles, and will never function until a live nerve serves the muscles.

2. In a compound wound of bone and nerve many months of healing followed by a prolonged period of convalescence is necessary before bone surgery may be performed. In those cases where bone grafting is performed a prolonged period of many months is again required for healing. These cases are often further complicated by extensive soft tissue loss so that still more delay is required for plastic repair. Therefore if nerve repair is postponed until bone repair is complete an extensive delay of from six to twelve months may occur. Postponement of nerve repair may result in:

   a. Continued retraction of nerve ends
   b. Excessive neuroma formation
   c. Extensive atrophy and fibrosis of muscles
   d. Ankylosis and malposturing of joints
   e. Faulty or delayed healing of bone

Therefore, when bone and nerve injury coexist, nerve repair must be granted primary consideration.

CARE OF THE JOINTS

Proper care of the paralyzed joints while the nerve is growing is paramount. Keeping a joint mobile until the nerve function returns is comparable to continued artificial respiration until normal breathing returns. Only those who realize the full significance of this comparison will be able to obtain full cooperation from their patient, for rehabilitation of a paralyzed joint does not mean an occasional fifteen minute physiotherapy seance but requires several hours a day of continuous work by the patient upon the paralyzed joint. The remaining normal upper extremity may be used to mobilize the joints of the injured one. The difference in the rate of return is vast in instances where the patient had a purpose or reward as his goal. Once a joint starts moving the place for convalescence is at home.

CARE OF THE ANESTHETIC PART

Avoid injury to the numb hand or foot. Protect the paralyzed hand with a thin leather glove while attempting to work, and a warm woolen or sheep lined glove when exposed during winter.

SPLINTS

Proper splinting without rigid immobilization is of chief importance. Failure to properly splint a wrist will result in permanent injury to the mobility of the wrist joint. Avoid immobilization of a normal joint. About thirty per cent of the soldiers admitted to Wakeman General Hospital with splinted arms had normal bones and joints. Faulty splinting and faulty joint posturing result in permanent injury. Tight splinting and bandaging produce ischemic contracture of the whole arm—muscles and nerves.

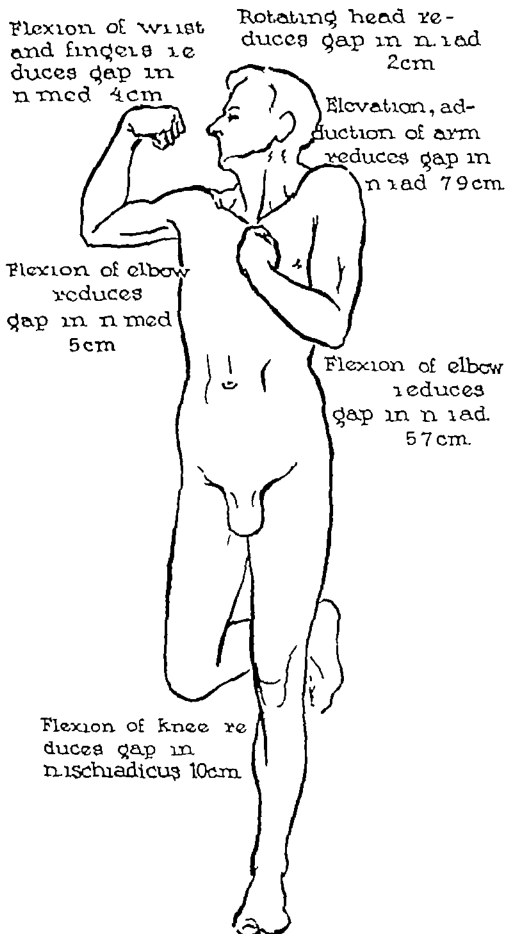

Flexion of wrist and fingers re duces gap in n med 4cm
Rotating head re- duces gap in n. rad 2cm
Elevation, ad- duction of arm reduces gap in n rad 7 9cm
Flexion of elbow reduces gap in n med 5cm
Flexion of elbow reduces gap in n rad. 5 7cm.
Flexion of knee re duces gap in n ischiadicus 10cm

Figure 19



Figure 10. The facies of a paratrooper with median nerve causalgia of nine months duration.



Figure 21 The patient in Figure 20 (eight weeks post-operative) There has been resection of soft neuroma of the median nerve in the arm.

OVERCOMING EXTENSIVE GAPS

The methods used for overcoming extensive gaps in nerves are those described by Babcock in 1927,[11] and Naffziger in 1921[12]

1. Utilizing the normal slack in nerves Two or three centimeters may be obtained in any of the long nerves by using adequate exposure and by properly freeing the nerve.
2. Joint posturing (Fig 19)
   a. Flexion of the wrist gives four centimeters to the median and ulnar nerves.
   b Adduction (elevation) of the shoulder gives seven centimeters slack to the radial nerve
   c Rotation of head to opposite side gives one or two centimeters of slack to roots of brachial plexus.
3. Bulb suture and stretching
   Two- or three stage operations.
4. Transplanting or re routing of nerves
   This is especially applicable to the median ulnar and tibial nerves, illustrated in anatomical drawings. In re-routing of nerves, great care must be taken to save all muscular branches. This is accomplished by splitting the sheath and stripping back the twigs. A motor twig need never be sacrificed in re routing a nerve

CAUSALGIA—SURGICAL MANAGEMENT

Causalgia is the term applied to excruciating burning pain that may develop following injury to the median and i nerves *This pain is of such severity* patients become morose, fearful, lose al terest in their life and surroundings an improperly treated, become narcotic add While the greatest percentage of cures been reported following sympathecto other procedures have been used with ; results Pain relief following sympathect is not always complete

The first treatment of causalgia shoul directed toward careful exploration of area of the injured nerve involved. A se causalgia cannot be cured by neuro alone, but if novocaine injected centr the injured part will temporarily stop pain, then resection of the scar followe neurorrhaphy will result in a complete c Fifteen such cases were recently cured this procedure by the author (ten me and five tibial) The causalgic pains did return after regeneration of the nerve author is well aware that this procedure performed many years ago is now c sidered obsolete by many operators ne theless, in carefully selected cases the res are excellent. These cases must be attac early during the first four or five month their pain, before an irreversible pain pa way is laid down, before the patient beco addicted to narcotic drugs, and bef morale is completely destroyed When peated sympathetic blocks fail to give e temporary relief resection and suture off better chance of cure than does surg sympathectomy

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[11]Babcock W W A tandard technique for operations on peripheral nerves with especial reference to the closure of large Surg Gyn Ob t 45 364-378 9 7

[12]Naff n H J C M hod to secure end to end suture f peripheral nerves. *Surg Gynec & Obst* 9 93-04 9

II

THE HAND

The most important consideration in injuries to the peripheral nerves of the upper extremity is the involvement of the hand In fact the development of the hand and of binocular vision are the two factors considered responsible for the evolution of man For, the hand is the antenna of the brain

In discussing the injuries to the peripheral nerves of the upper extremity so many references are made to paralysis and deformity to the intrinsic muscles of the hand that it is essential to be able to clearly visualize the normal anatomy of the hand

THE INTEROSSEI MUSCLES
(4 Dorsal—3 Volar)

The interossei lie in the intervals between the metacarpal bones They insert into the dorsal aponeuroses of the fingers on the basal phalanges.

DORSAL INTEROSSEI

Origin

Two heads from the borders of adjacent metacarpal bones.

Insertion

Into first, or basal phalanges of fingers into dorsal aponeurosis (Fig 22B) First and second insert into radial side of second and third fingers Third and fourth insert into ulnar side of third and fourth fingers

Action

Abduction of fingers Extension of third and second phalanges Flexion of first (*basal*) phalanges

Innervation

Ulnar by deep volar branch

VOLAR INTEROSSEI

Origin

By a single head First from ulnar border of second metacarpal Second from radial border of fourth metacarpal Third from radial border of fifth metacarpal

Insertion

First into ulnar side of dorsal aponeurosis of second finger

Action

Abduction (spread) of fingers. Extension of fingers as interossei Flexion of fingers as interossei.

Innervation

Ulnar deep volar branch

LUMBRICALES MUSCLES

Origin

From tendons of flexor digitorum profundus. Second and third—origin by one head. Fourth and fifth—origin by two heads

Insertion

Radial side of dorsal aponeurosis of second, third fourth, and fifth fingers.

Action

Flexion of the first (basal) phalanges (*interossei assist*)

OVERCOMING EXTENSIVE GAPS

The methods used for overcoming extensive gaps in nerves are those described by Babcock in 1927[11] and Naffziger in 1921[12]

1. *Utilizing the normal slack in nerves* Two or three centimeters may be obtained in any of the long nerves by using adequate exposure and by properly freeing the nerve
2. Joint posturing (Fig 19)
   a. Flexion of the wrist gives four centimeters to the median and ulnar nerves.
   b Adduction (elevation) of the shoulder gives seven centimeters slack to the radial nerve.
   c Rotation of head to opposite side gives one or two centimeters of slack to roots of brachial plexus
3. Bulb suture and stretching
   Two- or three-stage operations.
4. Transplanting or re routing of nerves
   This is especially applicable to the median, ulnar, and tibial nerves illustrated in anatomical drawings. In re-routing of nerves great care must be taken to save all muscular branches. *This is accomplished by splitting the* sheath and stripping back the twigs A motor twig need never be sacrificed in re routing a nerve.

CAUSALGIA—SURGICAL MANAGEMENT

Causalgia is the term applied to excruciating burning pain that may develop following injury to the median and t nerves. This pain is of such severity patients become morose, fearful, lose al terest in their life and surroundings an improperly treated, become narcotic add While the greatest percentage of cures l been reported following sympathecto other procedures have been used with g results Pain relief following sympathect is not always complete

The first treatment of causalgia shoul directed toward careful exploration of area of the injured nerve involved A se *causalgia cannot be cured by neuro* alone but if novocaine injected centra the injured part will temporarily stop pain then resection of the scar followed *neurorrhaphy will result in a complete c* Fifteen such cases were recently cured this procedure by the author (ten med and five tibial) The causalgic pains did return after regeneration of the nerve. author is well aware that this procedure, f performed many years ago, is now c sidered obsolete by many operators, nev theless, in carefully selected cases the res are excellent These cases must be attacl early during the first four or five month their pain before an *irreversible pain pa* way is laid down before the patient becor addicted to narcotic drugs, and bef morale is completely destroyed When peated sympathetic *blocks fail to give e* temporary relief, resection and suture offe better chance of cure than does surg sympathectomy

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[11] Babcock W W A standard technique for operations on peripheral nerves with especial reference to the closure of large g Surg Gyne Obst 45 364–378 1927

[12] Naffziger Howard C Methods secure end to end suture of peripheral nerves. *Surg Gyne & Obst* 32 193–204 1921

II

THE HAND

The most important consideration in injuries to the peripheral nerves of the upper extremity is the involvement of the hand In fact the development of the hand and of bi nocular vision are the two factors considered responsible for the evolution of man For the hand is the antenna of the brain

In discussing the injuries to the peripheral nerves of the upper extremity so many references are made to paralysis and deformity to the intrinsic muscles of the hand that it is essential to be able to clearly visualize the normal anatomy of the hand

THE INTEROSSEI MUSCLES
(4 Dorsal—3 Volar)

The interossei lie in the intervals between the metacarpal bones. They insert into the dorsal aponeuroses of the fingers on the basal phalanges.

DORSAL INTEROSSEI

Origin

Two heads from the borders of adjacent metacarpal bones.

Insertion

Into first, or basal phalanges of fingers into dorsal aponeurosis (Fig 22B) First and second insert into radial side of second and third fingers. Third and fourth insert into ulnar side of third and fourth fingers.

Action

Abduction of fingers. Extension of third and second phalanges. Flexion of first (*basal*) phalanges.

Innervation

Ulnar by deep volar branch

VOLAR INTEROSSEI

Origin

By a single head First from ulnar border of second metacarpal Second from radial border of fourth metacarpal Third from radial border of fifth metacarpal

Insertion

First into ulnar side of dorsal aponeurosis of second finger

Action

Abduction (spread) of fingers Extension of fingers as interossei Flexion of fingers as interossei.

Innervation

Ulnar deep volar branch.

LUMBRICALES MUSCLES

Origin

From tendons of flexor digitorum profundus. Second and third—origin by one head. Fourth and fifth—origin by two heads.

Insertion

Radial side of dorsal aponeurosis of second third fourth, and fifth fingers.

Action

Flexion of the first (basal) phalanges (*interossei assist*)

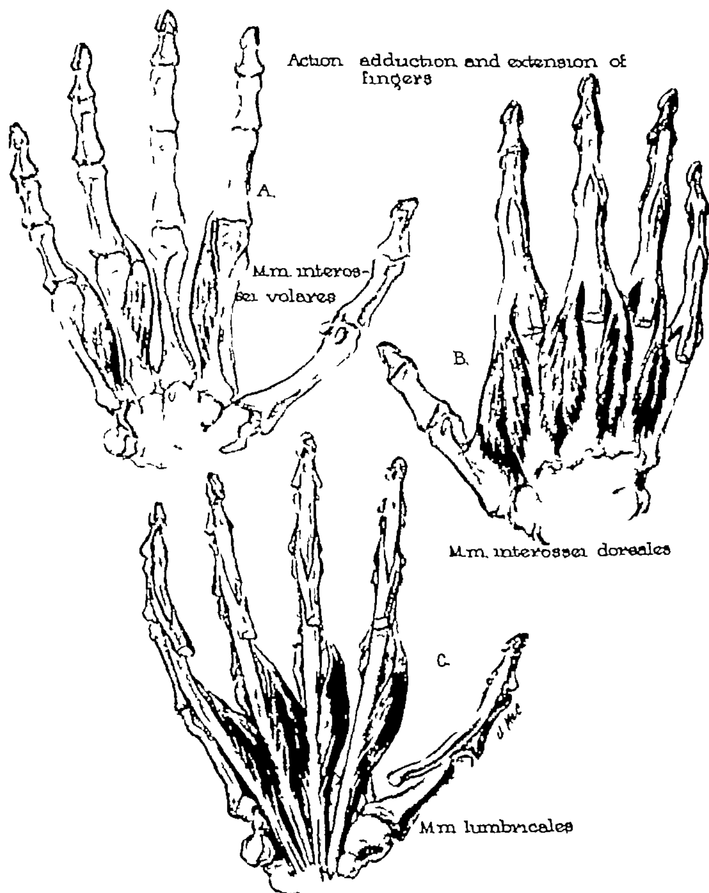
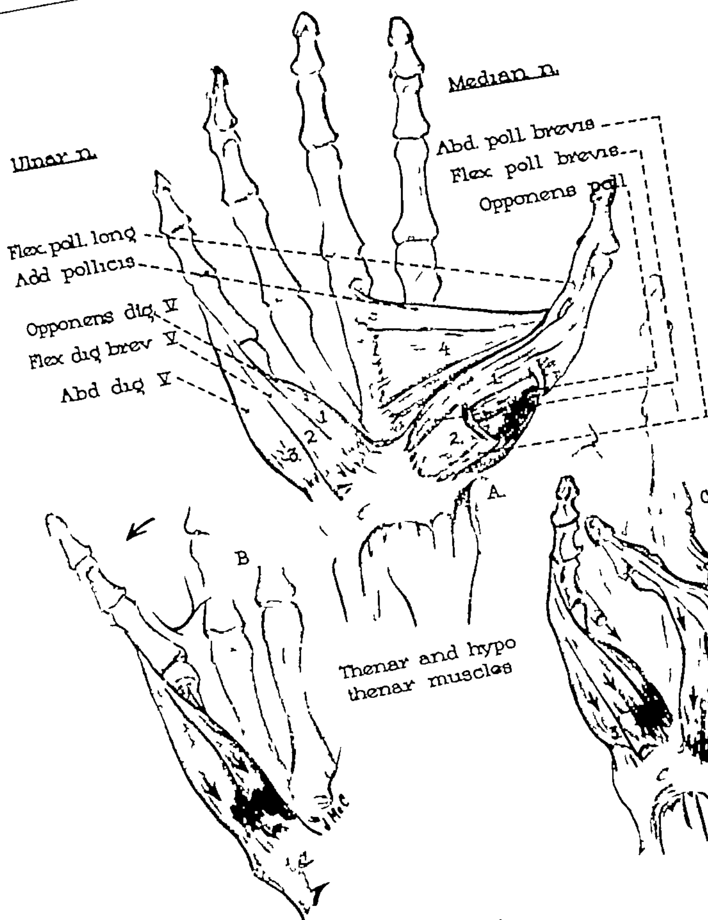

Action adduction and extension of fingers
A.
M.m. interossei volares
B.
M.m. interossei dorsales
C.
M.m lumbricales

Figure 22



Median n.
Ulnar n.
Abd. poll brevis
Flex poll brevis
Opponens poll
Flex poll. long
Add pollicis
Opponens dig V
Flex dig brev V
Abd dig V
1
2
3
4
A.
B
C
Thenar and hypo thenar muscles

Figure 23

Innervation

One or two radial, by the median nerve

Two or three ulnar, by the ulnar nerve (Fig 22C)

MUSCLES OF THE THENAR AND HYPOTHENAR REGIONS

Fig. 23A shows the anatomy of the thenar and hypothenar group of muscles The flexor abductor, and opponens muscles of both groups have a common insertion into the region of the transverse carpal ligament at the wrist.

These origins are shown in Fig 23A.

Action

Shown in Fig 23B and Fig 23C.

Nerve Supply

Median	Flexor pollicis brevis Opponens pollicis Abductor pollicis brevis Adductor pollicis
Ulnar	Flexor digiti V brevis Opponens digiti V (quinti) Abductor digiti V

FLEXOR TENDONS

The flexor tendons of the flexor digitorum sublimis insert into the middle phalanges. The tendons of the flexor digitorum profundus after piercing the sublimis tendons, insert into the terminal phalanges. None of the flexor tendons insert into basal phalanges.

Flexion of the basal (first) phalang action of the interossei and lumbrical 24A)

EXTENSOR TENDONS AND D APONEUROSES

Extensor tendons are called dors neuroses because they form a flat ex on the dorsal surface of the digit. E tendons consist of several tendons

1 Extensor digitorum communis t
2 Extensor digitorum propi tendo
3 Interossei and lumbricales tend

The extensor tendon extends only t phalanges the two distal phalanges tended by the combined action of terossei and lumbricales[1] (Fig 24B)

THE SHIFT OF THE APONEU SLEEVE

The anatomy and mechanism aponeurotic sleeve explains how t terossei and lumbricales may act, e flexors of the proximal phalangeal jo as extensors of the two distal joint 25A)

Transverse fibers form a dorsa over the back of the proximal phalanx the proximal joint (Fig 25C) but wh extensor tendon in stabilizing the pr joint, shifts the sleeve backward unt over the joint, the lumbricales and int pull on the lateral band to extend th two joints" (Fig 25B) [2]

---

[1] flexor tendon insert into the basal phalanges, while th extensor tendons only reach th basal phalanges. Extension is ve ative motion, preparing th fingers f flexion, like opening the jaws of a coop-shovel so th t t may grasp.

[2] Bunnell S *Surgery of the Hand* Philadelphia, J B. Lippinco t. Co. 1944.

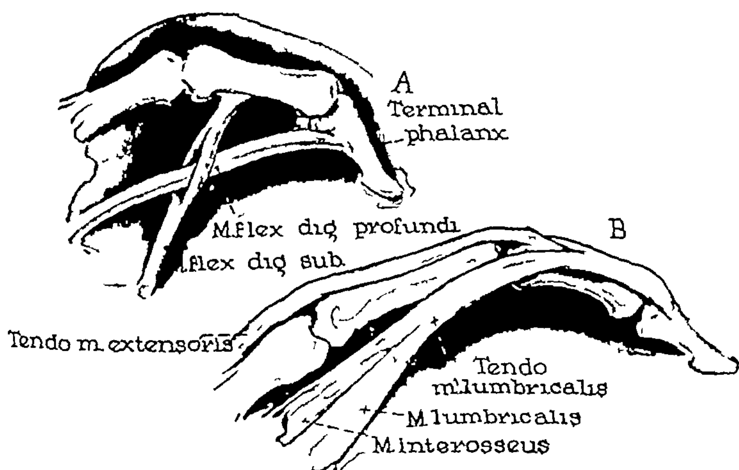

A
Terminal
phalanx
M.flex dig profundi
flex dig sub.
B
Tendo m. extensoris
Tendo
m. lumbricalis
M. lumbricalis
M. interosseus

Figure 24

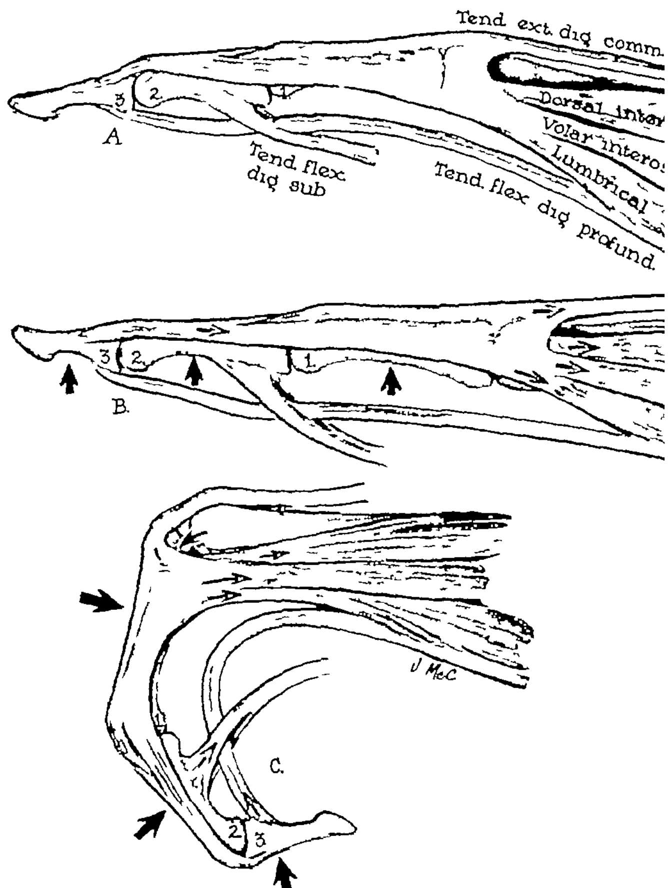


Figure 5 (Modified after Sterling Bunnell, *SURGERY OF THE HAND*)

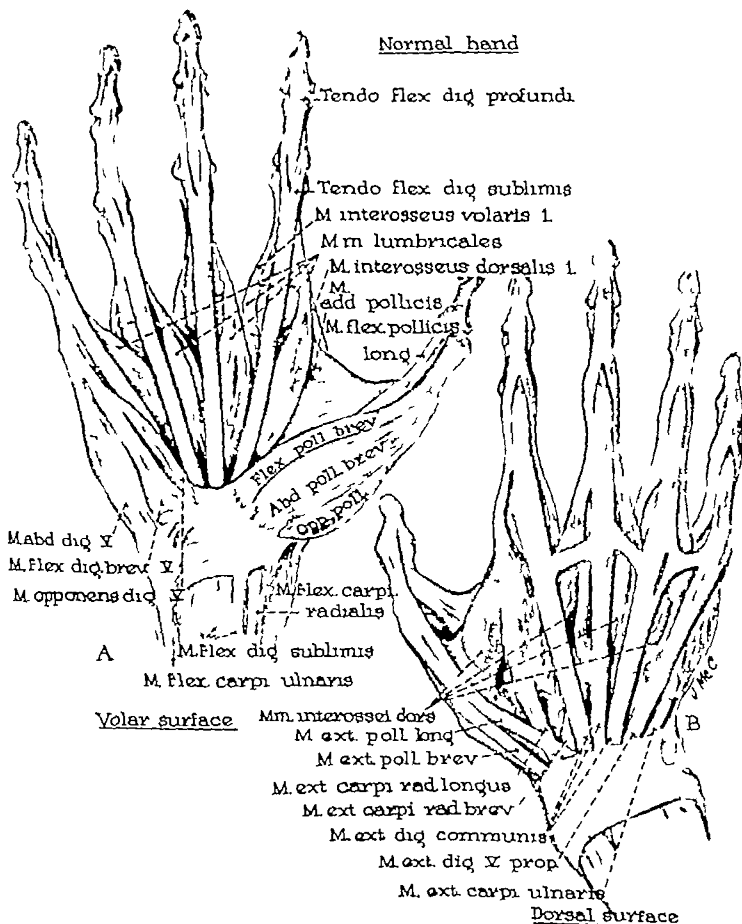

Normal hand
Tendo flex dig profundi
Tendo flex dig sublimis
M interosseus volaris 1
Mm lumbricales
M. interosseus dorsalis 1
M. add pollicis
M. flex pollicis long
Flex poll brev
Abd poll brev
opp poll
M abd dig V
M. flex dig brev V
M. opponens dig V
M. flex. carpi radialis
A
M. flex dig sublimis
M. flex. carpi ulnaris
Volar surface
Mm. interossei dors
M ext. poll long
M ext. poll brev
M. ext carpi rad longus
M. ext carpi rad brev
M. ext dig communis
M. ext. dig V prop
M. ext. carpi ulnaris
Dorsal surface
B

Figure 16

III

MEDIAN NERVE

The median nerve is the most important nerve of the hand It is the motor nerve for flexion of the first three fingers and for flexion and opposition of the thumb This constitutes the mechanism for grasping The median nerve is also the main nerve for sensation and tactile discrimination of the thumb and first three fingers It is by virtue of this innervation that the human hand can carry out its finely integrated functions and perform mechanical and artistic endeavors.

Paralysis of the median nerve makes the hand almost completely useless and the patient with median nerve paralysis can be seen to use the hand in the manner of an artificial limb either as a weight or to push an object aside In the deformity resulting, the fingers usually remain flexed while the thumb is unopposed giving the hand its characteristic name and appearance (*the ape hand*) With fingers extended the outstanding feature of median nerve palsy is the position of the unopposed thumb (Fig 27)

ANATOMY

The median nerve takes its origin from the medial and lateral cords of the brachial plexus and roots of origin are from the sixth, seventh, and eighth cervical and first thoracic roots of the spinal cord. It descends along the mesial portion of the arm along with the brachial artery and the ulnar nerve. It enters the forearm beneath the pronator teres *muscle and descends beneath the pro-*nator teres muscle and courses beneath the flexor digitorum sublimis lying on the profundus it becomes more superficial at the wrist lying in close proximity to and lateral to, the tendon of the palmaris longus muscle (Fig 28)

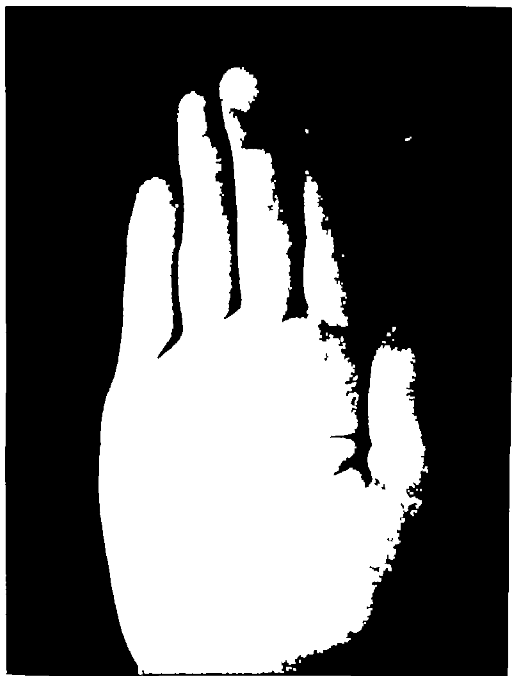


Figure 27 Paralysis of the median nerve. Note that there is loss of opposition of the thumb

COURSE AND DISTRIBUTION

a. Diagram (Fig 29)
b Motor and Sensory Supply

MOTOR

Forearm
- pronator teres
- flexor carpiradialis
- flexor digitorum profundus (lateral radial half)
- flexor digitorum sublimis
- flexor pollicis longus
- pronator quadratus

Hand
- abductor and opponeus pollicis (in the hand)
- flexor pollicis brevis (superficial head)
- lumbricales of index and middle fingers

SENSORY

sensation to palm
first and third digits
distal phalanges—first and second part of third digit, dorsum

TESTS OF MUSCLE FUNCTION AND THE INTACTNESS OF MEDIAN NERVE

NERVE	MUSCLE	TEST
median C5 6 7 8 and T1	pronator teres	with arm extended, resist supination
	flexor carpi—radialis	flex wrist against resistance to radial side
	flexor digitorum sublimis (all fingers)	resist extension at proximal inter phalanged joint
	flexor digitorum profundus I and II	resist extension at distal inter phalangeal joint
	flexor pollicis longus	resist extension of terminal phalanx
	abductor pollicis brevis	with nail at right angle to palm, raise thumb vertically against re sistance
	opponeus pollicis	touch tip of little finger against resistance with thumbnail parallel to palm

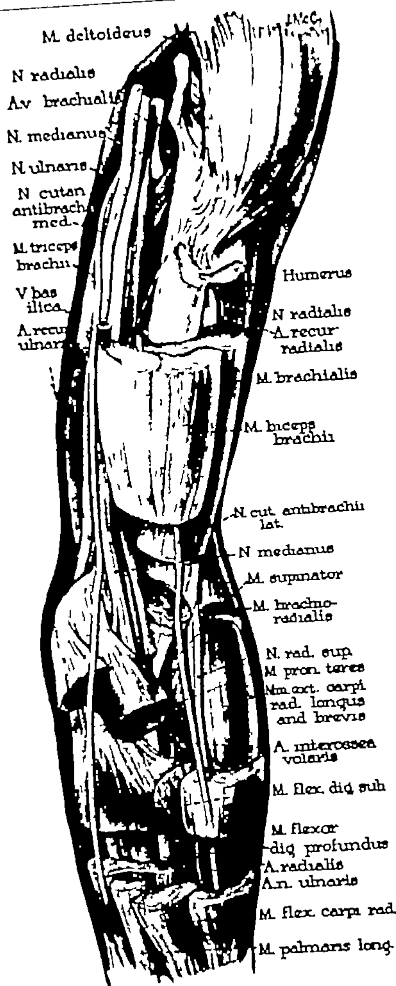

M. deltoideus
N radialis
A.v brachialis
N. medianus
N ulnaris
N cutan antibrach med.
M. triceps brachii
V bas ilica
A. recur ulnar
Humerus
N radialis
A. recur radialis
M. brachialis
M. biceps brachii
N. cut antibrachii lat.
N medianus
M. supinator
M. brachio-radialis
N. rad. sup.
M pron. teres
Mm ext. carpi rad. longus and brevis
A. interossea volaris
M. flex. dig sub
M. flexor dig profundus
A. radialis
A.n. ulnaris
M. flex. carpi rad.
M. palmaris long.

Figure 28

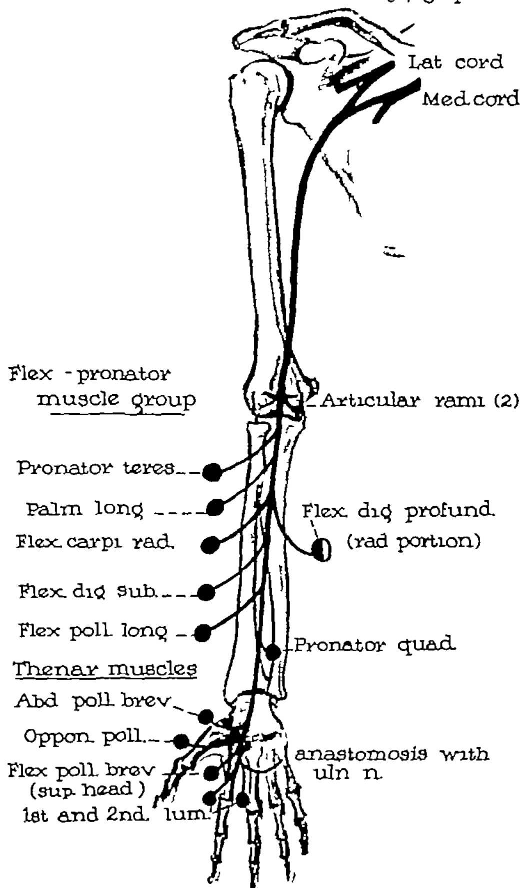


Figure 19 (Modified after Pitres and Testut, *LES NERFS EN SCHEMAS.*)



Figure 30. Median nerve paralysis. A sensory loss of the palmar surface.

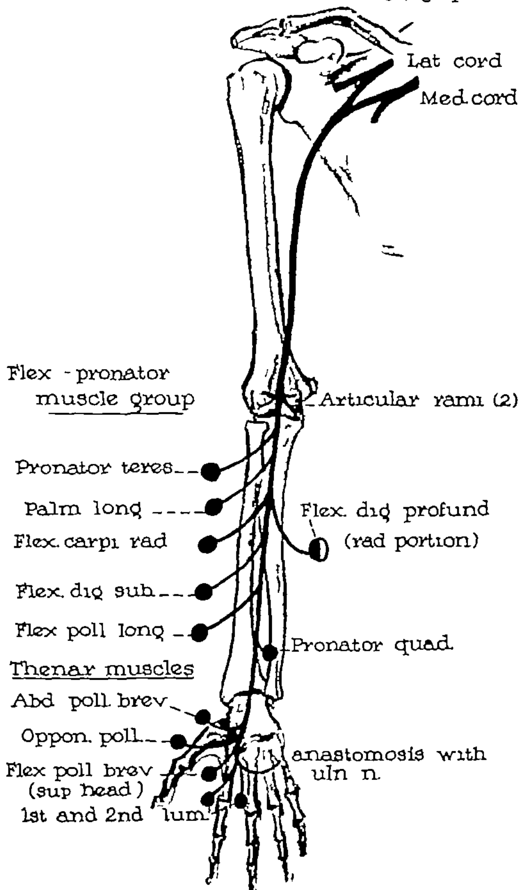


Figure 29. (Modified after Pitres and Testut, *LES NERFS EN SCHEMAS.*)



Figure 30 Median nerve paralysis. A sensory loss of the palmar surface



Figure 31 Median nerve paralysis. Complete loss of the flexion of the thumb and index finger



Figure 32 Median nerve paralysis. Loss of the ability to flex the index finger and thumb with incomplete flexion of the second finger

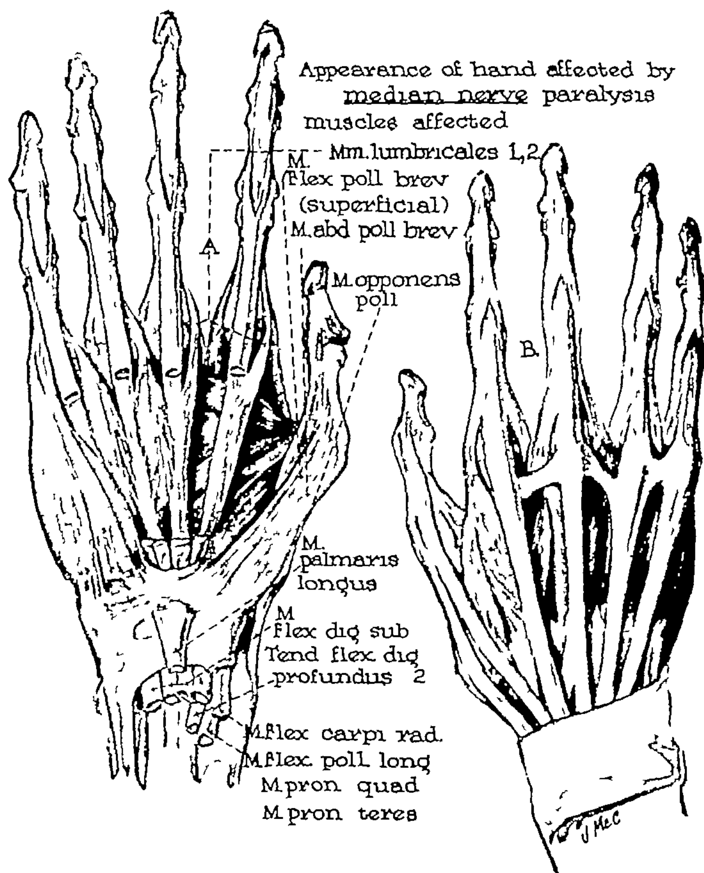

Appearance of hand affected by
median nerve paralysis
muscles affected
Mm.lumbricales 1,2
M.
Flex poll brev
(superficial)
M.abd poll brev
A
M.opponens
poll
B.
M.
palmaris
longus
M
Flex dig sub
Tend flex dig
profundus 2
M.flex carpi rad.
M.flex. poll. long
M.pron. quad
M.pron. teres
J McC

Figure 33



Figure 34 Incomplete nerve paralysis in the right hand. There is an incomplete loss of flexion in the index finger and in the opposition of the thumb in attempting to make a fist. The fist at the left is normal.

LEVEL OF LESION AND CHARACTERISTIC SYMPTOMS

A lesion above the elbow results in paralysis and atrophy of the pronators, and this results in the forearm being maintained in a mid-position In order to compensate for a lack of pronation it is necessary to abduct the flexed elbow, or, if the elbow is extended to rotate inwardly the whole arm at the shoulder Only a partial loss of wrist flexion is obtained by paralysis of brachioradialis (*flexor carpi radialis*) since the flexor carpi ulnaris supplied by the ulnar nerve produces some of the function. Paralysis of the flexor digitorum sublimis and the flexor digitorum profundus (radial portion) produces a loss of ability to flex the middle phalanx of all fingers and the terminal (third) phalanx of the index, middle finger and thumb

The index finger and thumb are the only fingers that lose all flexion in complete median nerve paralysis (Figs. 31 and 32) This is easily understood when it is remembered that the first phalanx of each finger is flexed by the interossei, the third (terminal) phalanx of the fourth and fifth digits by the deep flexors and both of these groups are supplied by the ulnar nerve. Flexion of the middle finger in median nerve paralysis is accomplished by either the innervation of the deep flexors by the ulnar or through the aponeurotic attachment to the second and third fingers.[1] Paralysis of the muscles of the thenar eminence produces atrophy and loss of ability to abduct the thumb as well as loss of ability to accurately oppose the thumb to the tips of the other fingers (Fig 33) There is also loss of ability to make a tight fist (Fig 34)

Sensory loss in median nerve paralysis (Fig 30) consists mainly in anesthesia (cutaneous) over the palmer surface of the thumb and lateral two and one-half fingers

Median nerve injuries are often associated with vasomotor and trophic disturbance. Spontaneous pain is observed frequently in median nerve injuries and is reviewed under *causalgia*

Of the 2037 peripheral nerves studied, 360 were median.

Surgical Anatomy of the Arm for Median Nerve

(Fig 28)

Incisions for Operative Exposure of Median Nerve

1 In the arm
2 In the forearm
3 In the cubital fossa
4 Combination of all three

In the arm The median nerve is exposed through a longitudinal incision ten to twelve centimeters in length over the mesial surface of the arm (Fig 35A Part 1) It lies in a plane between the borders of the biceps and triceps muscles The median and ulnar nerves can be palpated easily in the normal arm in this region. The injured nerve with a neuroma is almost always detected without difficulty by palpation in the arm in the region of wound.

In the forearm The median nerve is reached best by a longitudinal incision on the volar surface of the forearm (Fig 35A, Part 3) It is placed mesial to the border of the brachioradialis muscle Through this incision the pronator teres muscle is exposed. The median nerve lies deep within the substance of the muscle and is exposed by splitting the muscle in the direction of its fibers. Part 2 of the figure shows that this incision is a transverse incision which follows a flexion crease

[1]Yoskin, Joseph, C Affections f the peripheral nerves. *Looseleaf Medicine* New York, T Nelson & Sons, 932.

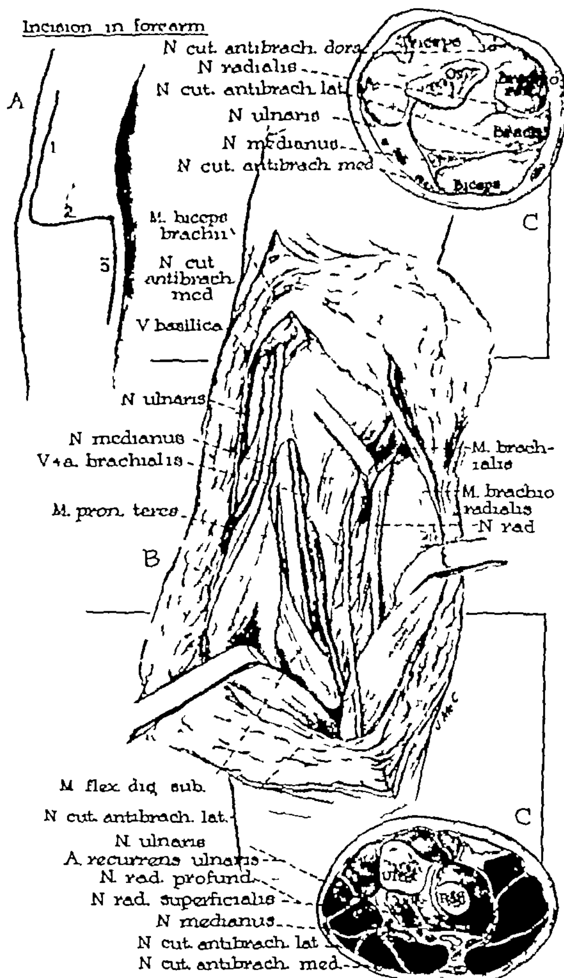

Incision in forearm
A
1
2
3
N cut. antibrach. dors.
N radialis
N cut. antibrach. lat.
N ulnaris
N medianus
N cut. antibrach. med
M. biceps brachii
N cut antibrach. med
V basilica
N ulnaris
N medianus
V+a. brachialis
M. pron. teres
B
M. brach- ialis
M. brachio radialis
N rad
C
M flex. dig. sub.
N cut. antibrach. lat.
N ulnaris
A recurrens ulnaris
N rad. profund.
N rad. superficialis
N medianus
N cut. antibrach. lat
N cut. antibrach. med.
C
Biceps
Ulna
Rad

Figure 35

in the cubital space When these incisions are united, a modified Z is formed (*Author's incision for the median nerve*) The flaps are now retracted and the median nerve may be traced along its greater course in the arm and forearm. This incision gives a very extensive exposure and at the same time avoids crossing a flexion crease.

Operative Exposure
(Fig 35B)

Cross Section of Arm

Above and below cubital space to show anatomic relations of median nerve (Fig. 35C)

Special Procedures

RE ROUTING OF MEDIAN NERVE

By re-routing the median nerve from deep beneath the flexor digitorum sublimis and pronator teres muscles a fifteen centimeter gap may be overcome. By stripping carefully the muscle twigs of the median nerve in the forearm no motor branch need ever be sacrificed.

Re routing the median nerve in the cubital space and in the forearm is used for overcoming extensive gaps in the arm forearm and hand This method was devised by Babcock in 1919[1]

Figs. 36–39 made in the operating room depict the closure of an eighteen centimeter gap of the median nerve in the wrist and hand By re routing the median nerve in the cubital space and from beneath the deep muscles of the forearm combined with flexion of the elbow and wrist, a gap of fifteen to twenty centimeters may be overcome By re-routing the median nerve in the cubital space and forearm, the severed median nerve at the wrist, was transplanted beneath the transverse carpal ligament into the hand, and sutured to the digital twigs in the hand

Fig 36A shows the author s Z-shaped incision in the cubital region and at the wrist and hand.

In Fig 36B both wounds are open. The median nerve is exposed beneath the pronator teres and flexor digitorum sublimis muscles The severed median nerve with central neuroma is exposed at the wrist, while the digital twigs are exposed in the hand through an incision in a flexor crease in the hand

Fig 37A shows stripping of the muscle twigs.

In Fig 37B a forceps has been passed beneath the flexor digitorum sublimis muscles to the open incision at the wrist. The neuroma is grasped at the wrist and gently withdrawn.

Fig 37C shows a new subfascial route made by passing the forceps superficially beneath the fascial layer between the two incisions.

Figs. 38A, 38B, and 38C show the method of fascial and skin closure Closure of the cubital wound is performed prior to nerve suture, since the cubital wound is more easily closed at this stage.

In Fig. 38D a new route is made for transplanting the median nerve into the hand by passing a forceps beneath the transverse carpal ligament.

Fig 39A shows the median nerve re routed into the hand and the digital twigs to the thumb and first two digits have been sutured to the main trunk.

In Fig 39B the elbow and wrist are maintained in flexion for three weeks by application of a posterior plaster shell.

[1] Babcock W W A standard technique for operations on peripheral nerves with especial reference to the closure of large gaps. Surg Gyn & Obst 45 364–378 1927

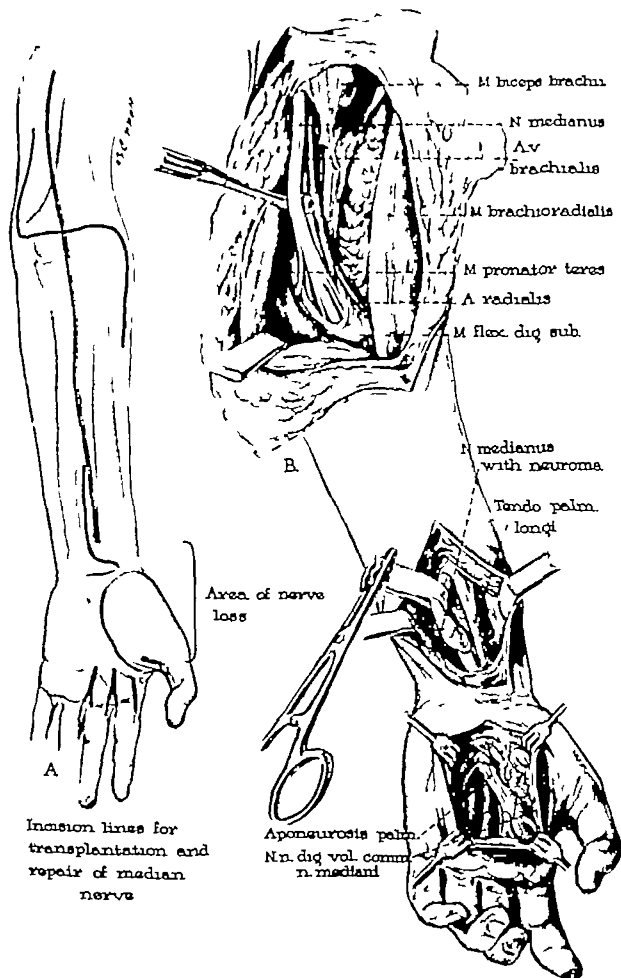
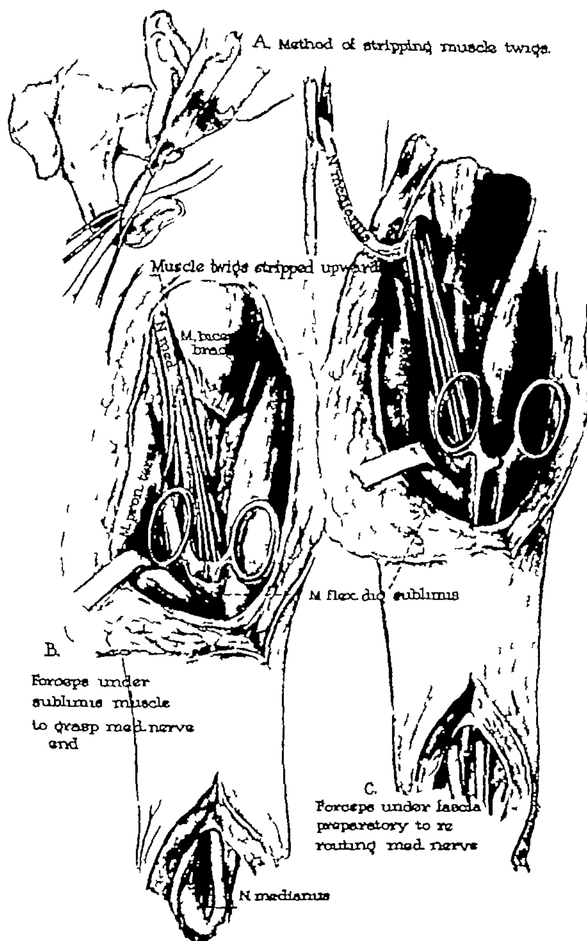

M biceps brachii
N medianus
A v brachialis
M brachioradialis
M pronator teres
A radialis
M flex dig sub
B
N medianus with neuroma
Tendo palm. longi
Area of nerve loss
A
Incision lines for transplantation and repair of median nerve
Aponeurosis palm.
Nn dig vol comm n mediani

Figure 36



A. Method of stripping muscle twigs.
Muscle twigs stripped upward
N. medianus
N. med.
M. pron. teres
M. flex. dig. sublimis
B.
Forceps under sublimis muscle to grasp med. nerve end
C.
Forceps under fascia preparatory to re routing med. nerve
N. medianus

Figure 37

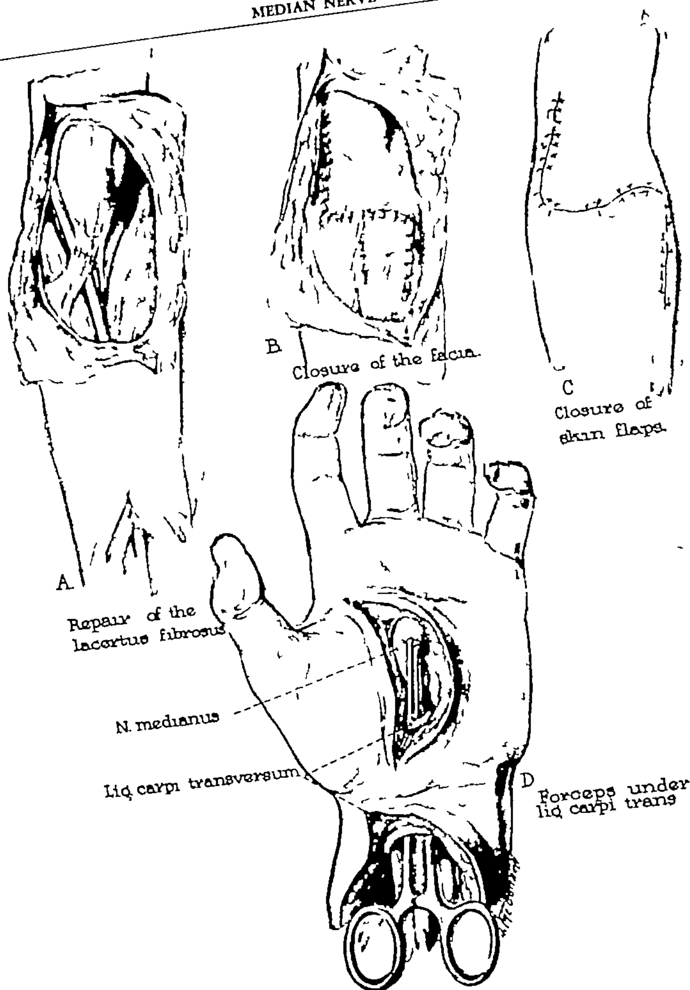

A.
Repair of the
lacertus fibrosus
B.
Closure of the facia.
C
Closure of
skin flaps.
N. medianus
Lig. carpi transversum
D
Forceps under
lig. carpi trans

Figure 38

LENGTH OF INCISIONS

There is a tendency to make excessively long incisions for exposure, repair and re routing of peripheral nerves.

Incisions over forty centimeters long in the upper extremity and over fifty centimeters long in the lower extremity have been observed Adequate surgery can be accomplished usually through much smaller incisions. It has been found satisfactory to re pair the injured nerve through an adequate incision at the site of the injury while re routing of the nerve, when necessary may be carried out through a second incision.

The skin and subcutaneous layers between the two incisions may be undermined by a suitable instrument along a fascial plane, and the nerve made free along its course. In this manner, excessive scar formation is avoided. The avoidance of subcutaneous scar in such instances is of even greater importance than the avoidance of scar in the skin Adequate exposure of the injured nerve must always take precedence over smaller incisions in those instances. The incision is planned so that it would result in a minimum of scar formation.

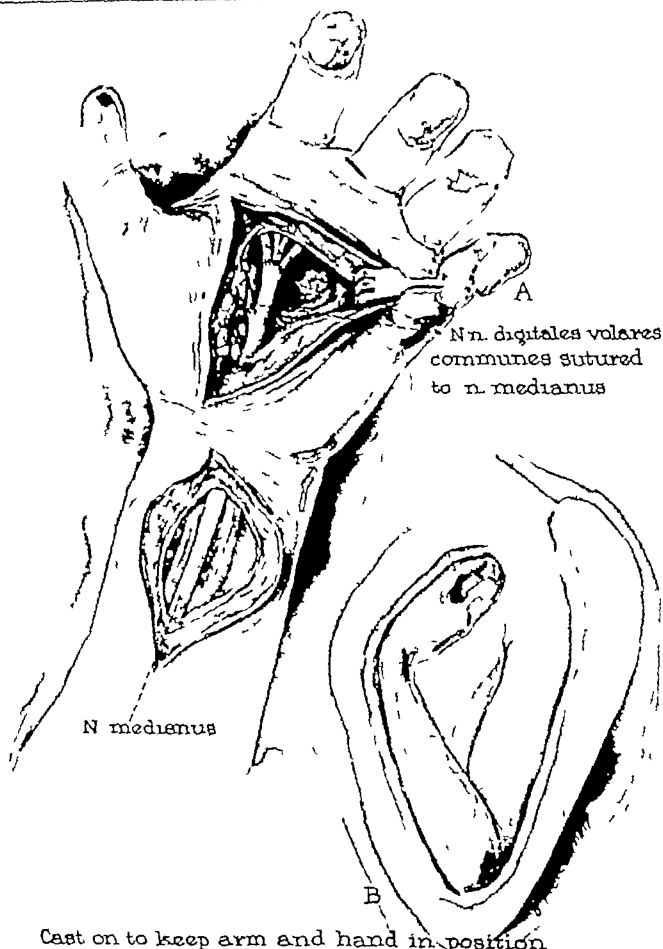

A
N n. digitales volares communes sutured to n. medianus
N medianus
B
Cast on to keep arm and hand in position

Figure 39.

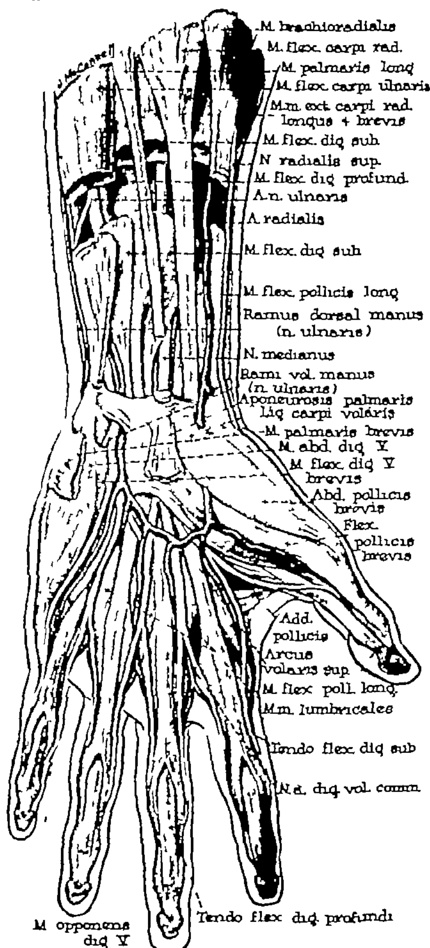

M. brachioradialis
M. flex. carpi rad.
M. palmaris long
M. flex. carpi ulnaris
Mm. ext. carpi rad. longus + brevis
M. flex. dig sub.
N radialis sup.
M. flex. dig profund.
A. n. ulnaris
A. radialis
M. flex. dig sub
M. flex. pollicis long
Ramus dorsal manus (n. ulnaris)
N. medianus
Rami vol. manus (n. ulnaris)
Aponeurosis palmaris
Lig carpi volaris
M. palmaris brevis
M. abd. dig V
M flex. dig V brevis
Abd. pollicis brevis
Flex. pollicis brevis
Add. pollicis
Arcus volaris sup.
M. flex poll. long.
Mm. lumbricales
Tendo flex. dig sub
N.a. dig. vol. comm.
Tendo flex dig. profundi
M opponens dig V

Figure 40

IV

INCISIONS IN THE HAND AND WRIST FOR EXPOSURE OF MEDIAN AND ULNAR NERVES

The most severe and disabling contracture scars are caused by longitudinal incisions crossing the flexion crease and transverse carpal ligament at the wrist and into the hand (Fig 8)

The median and ulnar nerves on the volar surface of the wrist may be exposed easily by using a transverse incision, in a flexion crease at the wrist (Fig. 41A)

When using this incision the transverse carpal ligament is also divided in the direction of its fibers. Should mobilization or transposition of the nerves be required the incision is then continued at right angles as far proximally as is needed [1] Neurorrhaphy of the median and ulnar nerves have been successfully performed through this incision alone. The operative exposure is shown in Fig 41C. Cross section of the wrist is shown in Fig. 41B

A combined incision for exposing and following the median nerve from the forearm into the hand consists of two parts, as shown in Fig 42A (*Author's incision*) The first part is an eight to ten centimeter longitudinal incision in the forearm ending at the wrinkle lines in the wrist. This incision is used for mobilization of the nerve in the forearm, it may be extended as far proximally as is found necessary The second part of this incision follows a flexion crease in the hand, and is used for exploring the median nerve in the hand. The small intact area of skin between the two incisions, along with the transverse carpal ligament, may be easily undermined and the nerve exposed beneath [2]

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[1] Woodhall, Barnes Personal communication to the author

[2] Sederberg, N. B.: The avoidance of contracture scars in elective surgery of the hand Personal communication to the author

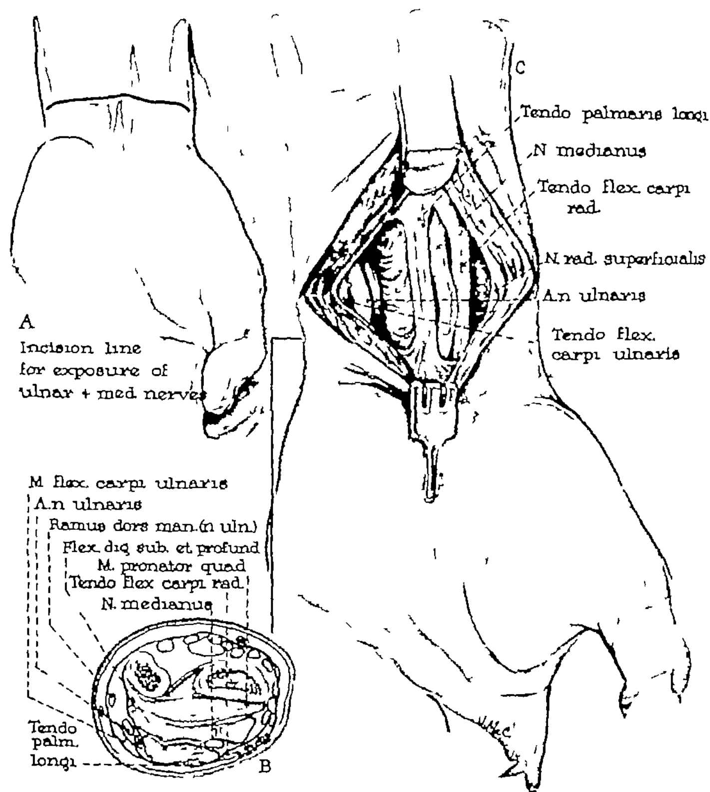

A
Incision line
for exposure of
ulnar + med nerves
C
Tendo palmaris longi
N medianus
Tendo flex. carpi
rad.
N rad. superficialis
A.n ulnaris
Tendo flex.
carpi ulnaris
M flex. carpi ulnaris
A.n ulnaris
Ramus dors man.(n uln.)
Flex. dig. sub. et profund
M. pronator quad
Tendo flex carpi rad
N. medianus
Tendo
palm.
longi
B

Figure 41

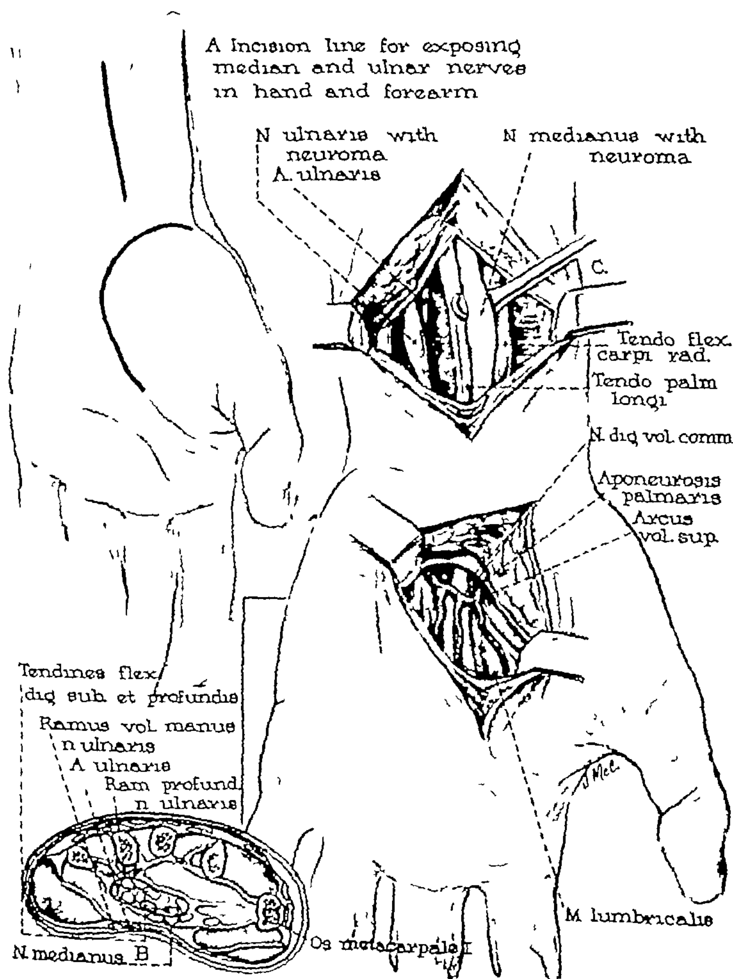

A Incision line for exposing median and ulnar nerves in hand and forearm
N ulnaris with neuroma
A. ulnaris
N medianus with neuroma
C.
Tendo flex. carpi rad.
Tendo palm longi
N. dig vol. comm
Aponeurosis palmaris
Arcus vol. sup.
Tendines flex dig sub et profundis
Ramus vol. manus n ulnaris
A ulnaris
Ram profund. n ulnaris
N medianus B
Os metacarpale I
M lumbricalis

Figure 41

V

THE ULNAR NERVE

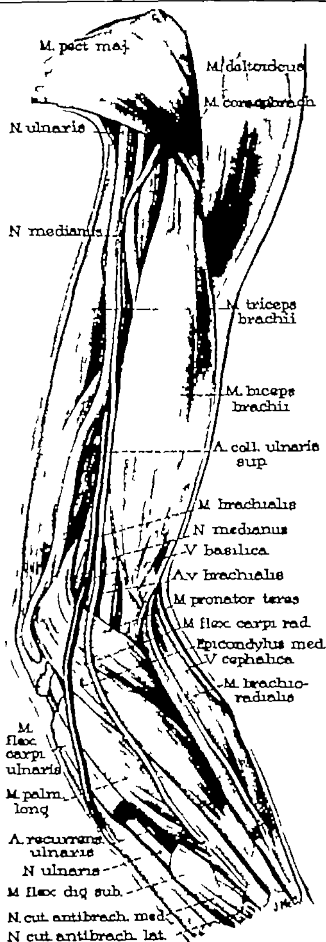
The ulnar nerve supplies almost all the small muscles of the hand and paralysis of this nerve produces the most severe wasting of the hand. This wasting is caused by atrophy of the interossei, the thenar muscles, and heavy adducter of the thumb (Fig 43) Since sensation in the thumb and first two fingers and flexors, and opposition of thumb is maintained by the median nerve, a fairly useful member remains still for holding grasping and feeling Of the 2037 nerve injuries studied, 390 were ulnar

ANATOMY

The ulnar nerve is derived fro
cord of the brachial plexus and
from the eight cervical and fi
segments of the spinal cord It l
mesial side of the limb in all its c
arm it lies between the biceps
muscles, accompanied by the n
and the brachial artery It pas
ulnar notch at the elbow pierc
carpi ulnaris muscle, and lies l
muscle on the volar surface of
all the way to the wrist (Fig 4



Figure 43 Ulnar nerve paralysis. Atrophy of the first dorsal interosseous and adductor pollicis produces the depression known as "anatomical snuff box."



M. pect maj.
M. deltoideus
M. coracobrach.
N. ulnaris
N. medianus
M. triceps brachii
M. biceps brachii
A. coll. ulnaris sup.
M. brachialis
N. medianus
V. basilica
A.v. brachialis
M. pronator teres
M. flex. carpi rad.
Epicondylus med.
V. cephalica
M. brachio-radialis
M. flex. carpi ulnaris
M. palm. long.
A. recurrens ulnaris
N. ulnaris
M. flex. dig. sub.
N. cut. antibrach. med.
N. cut. antibrach. lat.

Figure 44.

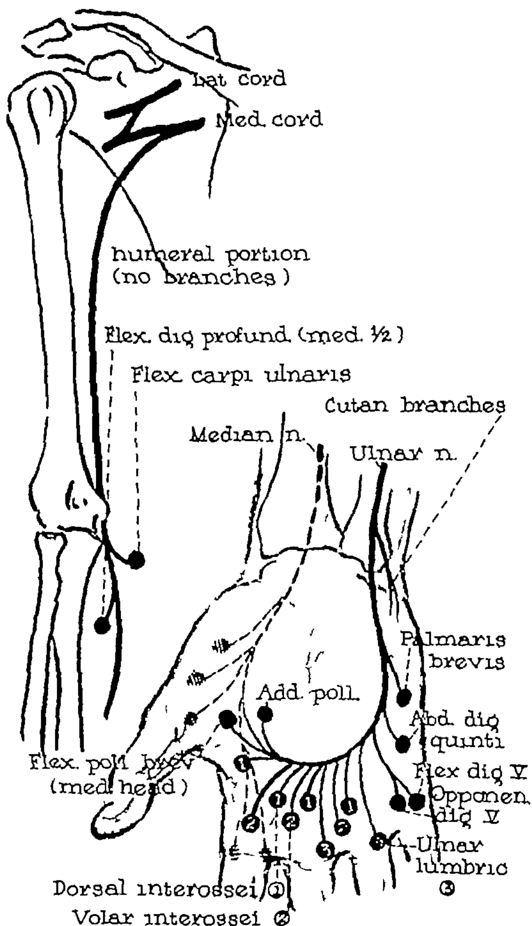


Figure 45 (Modified after McDonald Green, and Lange *CORRELATIVE NEUROANATOMY*)

COURSE AND DISTRIBUTION

a. Diagram (Fig. 45)
b Motor and Sensory Supply

MOTOR

Forearm
- flexor carpi ulnaris
- flexor digitorum profundus (ulnar half)

Hand
- interossei
- lumbricales—third and fourth
- adductor pollicis
- flexor pollicis brevis (inner head)

- flexor digiti (quinti) v
- opponeus digiti v
- abductor digiti v
- palmaris brevis

SENSORY

Sensation to medial half of hand, fifth finger and one half of fourth over volar and dorsal surface.

CHARACTERISTIC SYMPTOMS OF ULNAR NERVE PARALYSIS

Paralysis of the ulnar nerve causes atrophy of the interossei (Fig 47), thenar and hypothenar muscles, flexor carpi ulnaris, and the ulnar head of flexor digitorum profundus. This results in the claw hand deformity especially marked in the fourth and fifth fingers (Fig 46)

Mechanism of Claw Hand Deformity

The interossei normally flex the first phalanges upon the palm while they extend

TESTS OF MUSCLE FUNCTION AND THE INTACTNESS OF ULNAR NERVE

NERVE	MUSCLE	TEST
ulnar (C8T1)	flexor carpi ulnaris	with hand extended abduct little finger and tendon of flex carpi ulnaris can be seen as it fixes point or origin of abductor digiti minimi
	flexor digitorum profundus 3 and 4	resist extension at distal inter phalangeal joint
	abductor digiti minimi	resist abduction of little finger with hand extended
	dorsal interossei 1 2 3 4	abduct (spread) against resistance all fingers except the fifth, with palm down
	palmar interossei 2, 3 4	abduct against resistance all fingers except thumb. Fingers are brought together tightly Patient tries against resistance to retain a strip of paper between adjacent fingers
	abductor pollicis	with thumb nail at right angle to palm, hold paper between thumb and palm



Figure 46 Ulnar nerve paralysis, showing the area of anesthesia.

the two distal phalanges Paralysis of the interossei and of the two mesial lumbricales results in the extension of first phalanges by the unopposed extensor digitorum communis, and flexion of the second phalanges by the unopposed action of the flexor digitorum sublimis (Fig 48) This results in the claw hand deformity This is more marked in the fourth and fifth finger than in the remaining ones because the lumbricales, which are supplied by the median nerve substitute for the function of the paralyzed interossei

Another sign of ulnar paralysis is inability to spread the fingers or to bring them together The little finger remains abducted by the unopposed action of the abductor minimi digiti (Fig 47) Atrophy of the thenar and hypothenar muscles as well as the interossei gives the skeletal appearance to the hand (Fig 47) Paralysis of the adductor pollicis gives rise to "*Froments Sign*" (Fig 49)

Surgical Anatomy
(Fig 44)

INCISIONS FOR OPERATIVE EXPOSURE

1 In the arm
2 At the ulnar notch
3 In the forearm

In the arm The ulnar nerve is exposed through the same incision as that used for the median nerve. This is a 10 to 12 centimeter longitudinal incision over the medial surface of the arm (Fig 50B)

In the forearm The ulnar nerve is explored through Part 3 (Fig 50B) This consists of a longitudinal incision of variable length (10 to 15 centimeters) on the volar surface of the forearm along the border of the flexor carpi ulnaris muscle

At the ulnar notch The ulnar nerve is explored through a six or seven centimeter curved incision over the region of the medial epicondyle (Fig 50B, Part 2) This is used to explore the ulnar nerve in the ulnar notch and to transplant the nerve to the volar surface in the cubital space

Operative Exposure
(Fig 50A)

SPECIAL PROCEDURES

If necessary, a more radical transplantation may be performed by placing the ulnar nerve beneath the fleshy portion of the flexor carpi ulnaris muscle In that event the muscle is severed from its fascial attachment to the ulna so that it may be easily repaired.

STRIPPING OF MOTOR TWIGS

It is very important to carefully strip the motor twigs to the flexor carpi ulnaris muscle flexor digitorum profundus, medial one half and twig to the elbow joint. Failure to strip the twig to the elbow joint may cause tension on the twig and result in a painful elbow joint A ten centimeter gap may be overcome by proper ulnar nerve transplantation.



Figure 47 Ulnar nerve paralysis, showing interossei atrophy

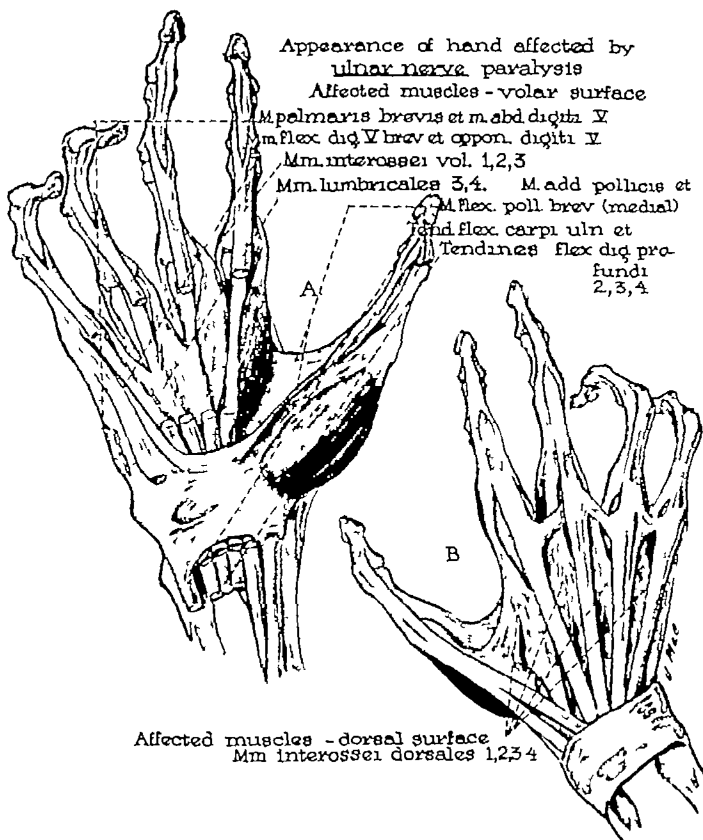
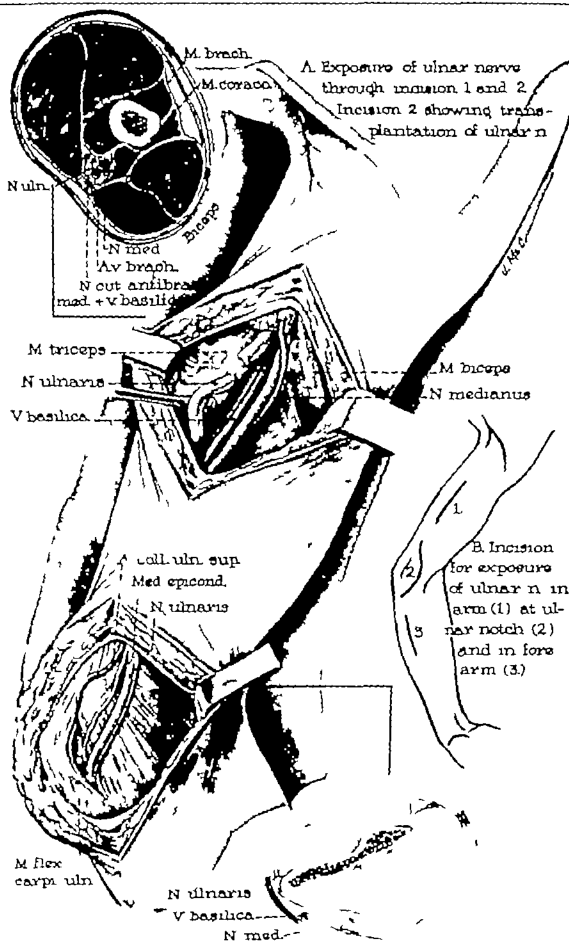

Appearance of hand affected by
ulnar nerve paralysis
Affected muscles - volar surface
M.palmaris brevis et m.abd.digiti V
m.flex. dig.V brev et oppon. digiti V
Mm.interossei vol. 1,2,3
Mm.lumbricales 3,4.
M.add pollicis et
M.flex. poll. brev (medial)
Tend.flex. carpi uln et
Tendines flex dig profundi
2,3,4
A
B
Affected muscles - dorsal surface
Mm interossei dorsales 1,2,3 4

Figure 41



Figure 49 Froment sign in left ulnar nerve paralysis. The patient is grasping a glass slide with either thumb and fore finger


M. brach.
M. coraco.
A. Exposure of ulnar nerve through incision 1 and 2. Incision 2 showing transplantation of ulnar n
N uln.
Biceps
N med
A.v brach.
N cut antibra
med. + v. basilic
M triceps
N ulnaris
V basilica
M biceps
N medianus
1
2
3
B. Incision for exposure of ulnar n. in arm (1) at ulnar notch (2) and in fore arm (3.)
Coll. uln. sup.
Med epicond.
N ulnaris
M flex carpi uln
N ulnaris
V basilica
N med.

Fig

VI

THE MEDIAN AND ULNAR NERVE COMBINED

In combined paralysis of the median and ulnar nerve a most severe and disabling de formity of the hand results Paralysis and atrophy is present of all the muscles on the anterior surface of the forearm, pronation and flexion of the hand upon the wrist are lost. Any degree of wrist flexion that may remain is performed by the substitution of the long and short extensors of the thumb

The thenar and hypothenar eminences are atrophied giving a marked flatness to the hand. In spite of the paralysis of all the flexors, the fingers are usually flexed This flexion, present when the wrist is hyperextended, is caused by the stretching of the flexor tendons of the hand There is always complete loss of opposition and abduction of the thumb (Figs. 51–55)

The extreme griffe hand is observed in incomplete median and ulnar nerve injuries, and also during regeneration of the nerves. It is produced by the increasing tone of the flexors of the second and third phalanges of the fingers from the flexor digitorum profundus muscle (Fig 56) when they are deprived of the antagonism of the interossei which usually extend to the second and third phalanges. The flexed fingers flatness of the hand, and unopposable thumb, produces the so-called four-fingered ape hand (Figs. 51–55) It is well to prevent the severe flexion of the fingers by judiciously applied splinting and preventing hyperextension of the wrist and fingers Sensory loss is illustrated in Figs 57 and 58

The brachial artery is often involved in combined median and ulnar nerve injuries because of their proximity in the middle third of the arm. Vascular disturbance of the fingers and occasional gangrene of the finger tips are observed (Fig 59)



Figure 51 An " pe hand caused by combined median and ulnar nerve paralysis.



Figure 52 Dorsum of hand showing effect of a combined median and ulnar nerve paralysis.



Figure 53 Combined median and ulnar nerve paralysis as seen in the right hand compared to the normal left hand.



Figure 54. Combined median and ulnar nerve paralysis as seen in the right hand compared to the normal left hand



Figure 55 A severe claw hand with severe atrophy of the thenar muscles flexor pollicis brevis, opponens pollicis and abductor pollicis.

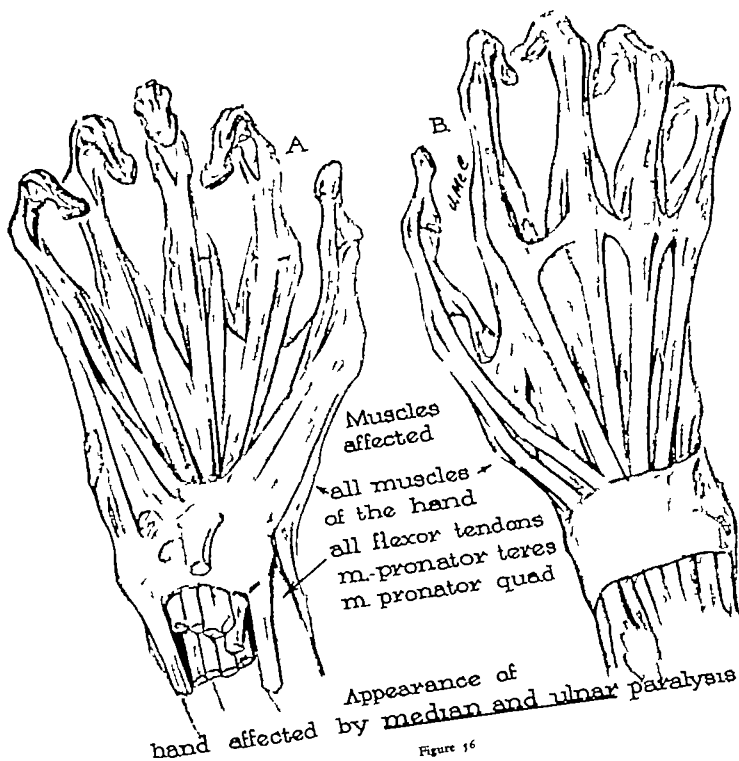

A
B
Muscles
affected
all muscles
of the hand
all flexor tendons
m.-pronator teres
m. pronator quad
Appearance of
hand affected by median and ulnar paralysis

Figure 56

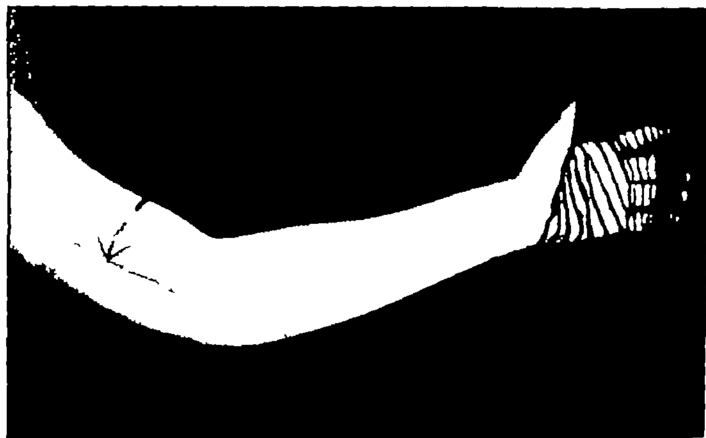


Figure 57 Sensory loss.

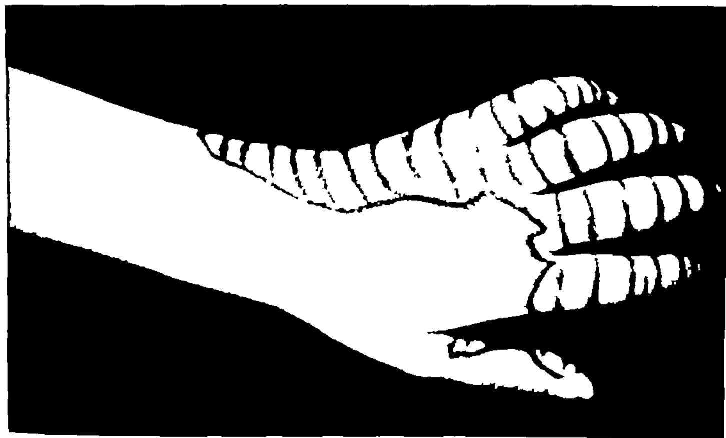


Figure 58 Median and ulnar nerve paralysis with sensory loss.

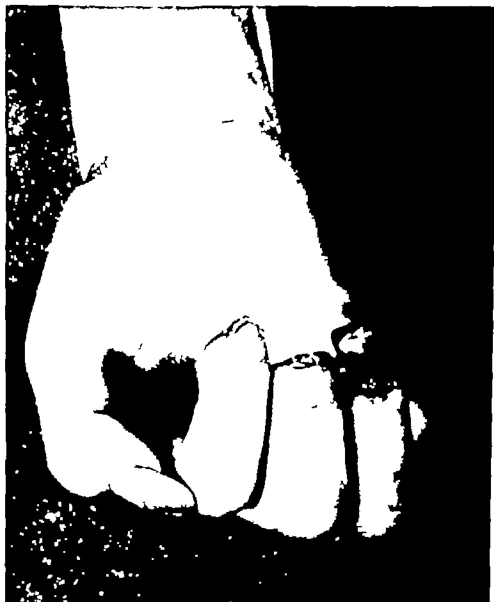


Figure 59 Gangrene of the finger tips produced by a combined injury to the median and ulnar nerve, and the brachial artery

VII

THE RADIAL NERVE

The radial nerve is the motor nerve for extension (dorsiflexion) of the wrist and fingers including the thumb The fingers remain in the position of a partially opened pliers and can only grasp an object after they are extended by help of the normal hand The moment the artificial extension is released the fingers drop to their characteristic position. The wrist hangs in the characteristic flexed position of wrist drop (Figs. 60 and 61) Although a radial nerve injury is considered the most commonly observed nerve injury, this was not true in war wounds Of the 2037 nerve injuries studied, 284 were radial.

ANATOMY

The radial nerve is the direct continuation of the posterior cord of the brachial plexus Its fibers are derived from the sixth seventh, and eighth cervical and first thoracic segments of the spinal cord It accompanies the profunda artery around and behind the humerus and in the radial groove. (Fig 62A) It courses down beneath the upper portion of the brachioradialis muscle, lateral to the cubital space, where it divides into deep (*dorsal interosseus*), *superficial* (*cutaneous*), and muscular branches (Fig 62B)

COURSE AND DISTRIBUTION

a Diagram (Fig 63)

b *Motor and Sensory Supply*

Motor

Arm:
- triceps
- brachioradialis
- extensor carpi radialis longus
- anconeus

Forearm (*by deep radial branch*):
- extensor carpi radialis brevis
- extensor digitorum communis
- extensor digiti quinti proprius
- extensor carpi ulnaris
- supinator
- abductor pollicis longus
- extensor pollicis brevis
- extensor pollicis longus
- extensor indicis proprius

Sensory

Sensory loss consists of a variable area over dorsum of hand and thumb (Fig 60)

TESTS OF MUSCLE FUNCTION AND THE INTACTNESS OF THE RADIAL NERVE

Nerve	Muscle	Test
radial C 5 6 7 8 T 1	triceps	extend forearm against resistance supporting forearm against gravity
	brachioradialis	in natural position flex forearm against resistance
	extensor carpi radialis longus	with fingers extended extend wrist to radial side against resistance
	supinator	with arm extended pronate against resistance
	extensor digitorum communis	resist flexion at metacarpo-phalangeal joint
	extensor carpi ulnaris	extend wrist joint to ulnar side against resistance
	abductor pollicis longus	abduct thumb at right angle to palm against resistance
	extensor pollicis brevis	resist attempt to flex thumb at metacarpo-phalangeal joint
	extensor pollicis	resist flexion at inter phalangeal joint

LEVEL OF LESION AND CHARACTERISTIC SYMPTOMS

1 When the lesion is at level of lower axilla as is often observed in bullet and shrapnel wounds of shoulder and axilla the entire nerve is involved including paralysis of triceps muscle.
2 In the middle third of the arm by fractures of humerus
   a. The triceps remains normal
   b Paralysis of the extensor supinator group and all the extensors below it, producing wrist drop (Figs. 60 64)
3 In the middle third of the forearm
   a. Paralysis of the deep radial nerve gives isolated paralysis of extensors of the thumb and index finger (Figs. 65 and 66)

SURGICAL ANATOMY
(Fig 62)

INCISIONS FOR SURGICAL EXPLORATION

1 In the arm
2. In the forearm
3 Lateral to cubital fossa

In the arm The radial nerve is exposed through Part I of the incision in Fig 67A. This is longitudinal or oblique incision over the lateral surface of the arm parallel to the radial groove.

In the forearm The radial nerve is exposed through Part 3 in Fig 67A, a longitudinal incision over the volar surface of the forearm. It is placed laterally over the border of the brachioradialis muscle.

At the cubital fossa The radial nerve is

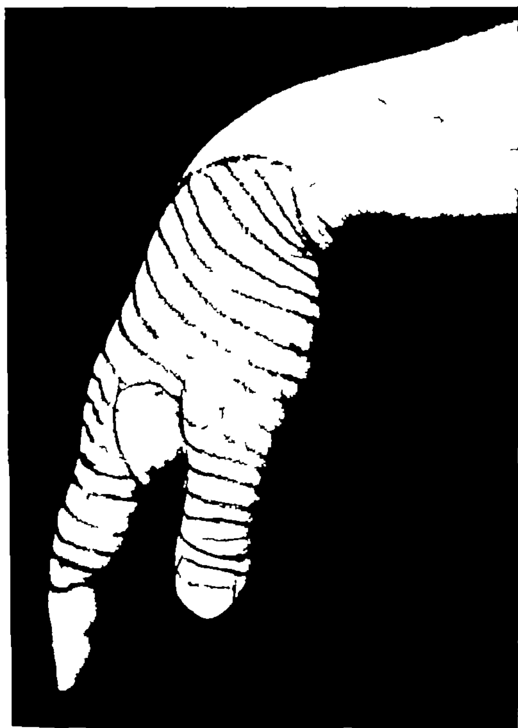


Figure 60. Radial nerve palsy causing a wrist drop. The outlined area is the region of anesthesia.

exposed by a five or six centimeter semi circular flap incision as shown in Part 2 of Fig 67A. This incision is made laterally over the region of the lateral epicondyle in order to avoid crossing the flexion crease When this flap is retracted medialwards, the nerve may be exposed as it lies between the biceps tendon and the brachioradialis muscle From here it may be followed along its course beneath the brachioradialis muscle to its point of division into the deep and superficial radial nerves.

OPERATIVE EXPOSURE (Fig 67B)

CROSS SECTION (Fig 62A)

SPECIAL PROCEDURES FOR OVERCOMING GAPS IN THE RADIAL NERVE

Taking up normal slack rotating the head, elevation and adduction of the arm, and flexion of the elbow after freeing the nerve where it divides.[1]

[1] Babcock W W A standard technique for operations on peripheral nerves with especial reference to the closure of gaps. *Surg Gyne & Obst* 45 364–378 1927



Figure 61 Nerve palsy causing a wrist drop An attempt has been made to raise the right wrist and to spread the fingers of that hand as has been done in the normal left hand shown at the right of the picture

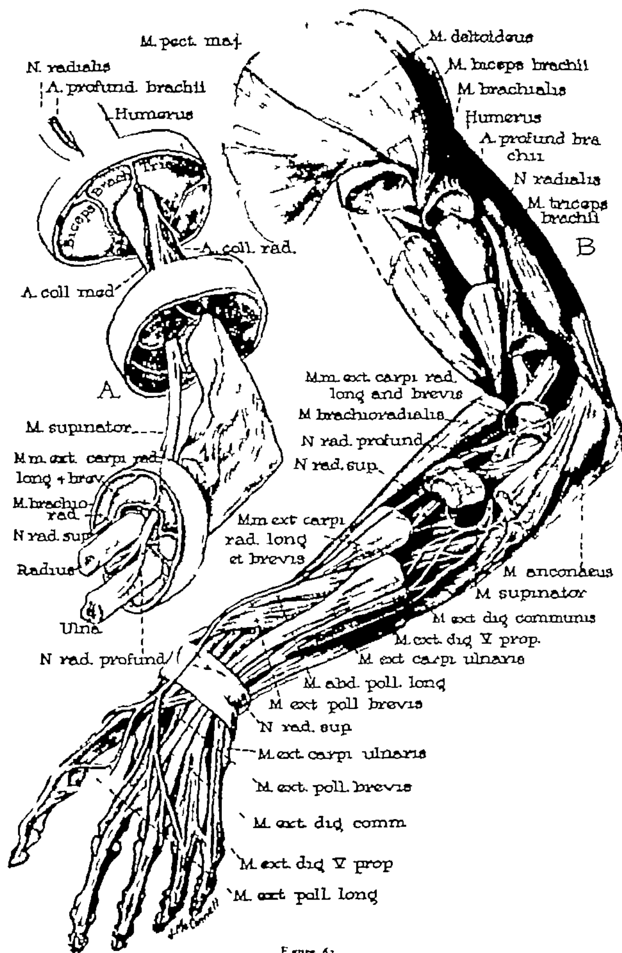

M. pect. maj.
N. radialis
A. profund. brachii
Humerus
Biceps
Brach
Tric
A. coll. rad.
A. coll med
A.
M. supinator
Mm. ext. carpi rad. long + brev.
M. brachio-rad.
N rad. sup
Radius
Ulna
N rad. profund
Mm ext carpi rad. long et brevis
M. deltoideus
M. biceps brachii
M. brachialis
Humerus
A. profund bra chii
N radialis
M. triceps brachii
B
Mm. ext. carpi rad. long and brevis
M brachioradialis
N rad. profund
N rad. sup.
M anconaeus
M supinator
M ext dig communis
M. ext. dig V prop.
M ext carpi ulnaris
M. abd. poll. long
M ext poll brevis
N rad. sup
M. ext. carpi ulnaris
M. ext. poll. brevis
M. ext. dig comm
M. ext. dig V prop
M. ext poll. long

Figure 62

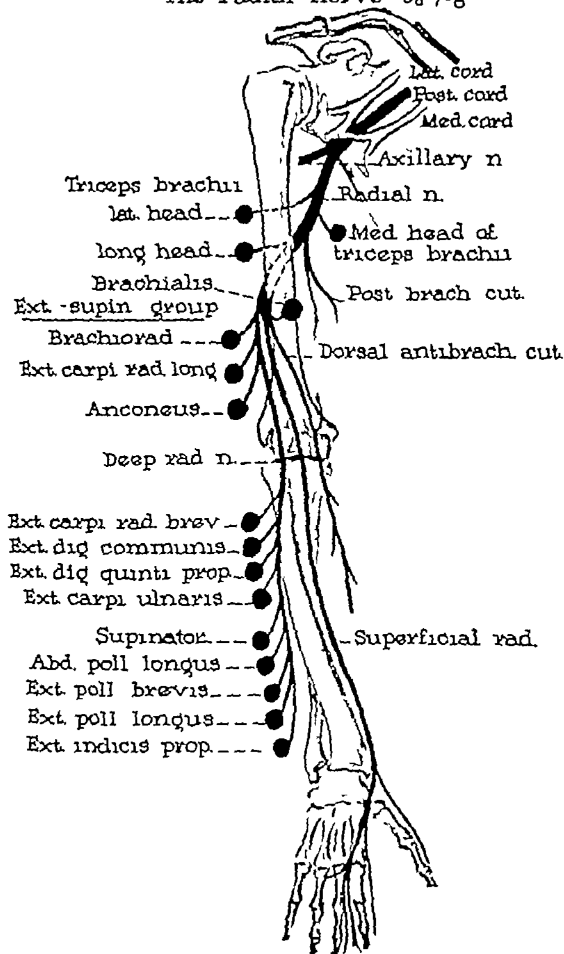


Figure 63 (Modified after Pitres and Testut, LES NERFS EN SCHEMAS)

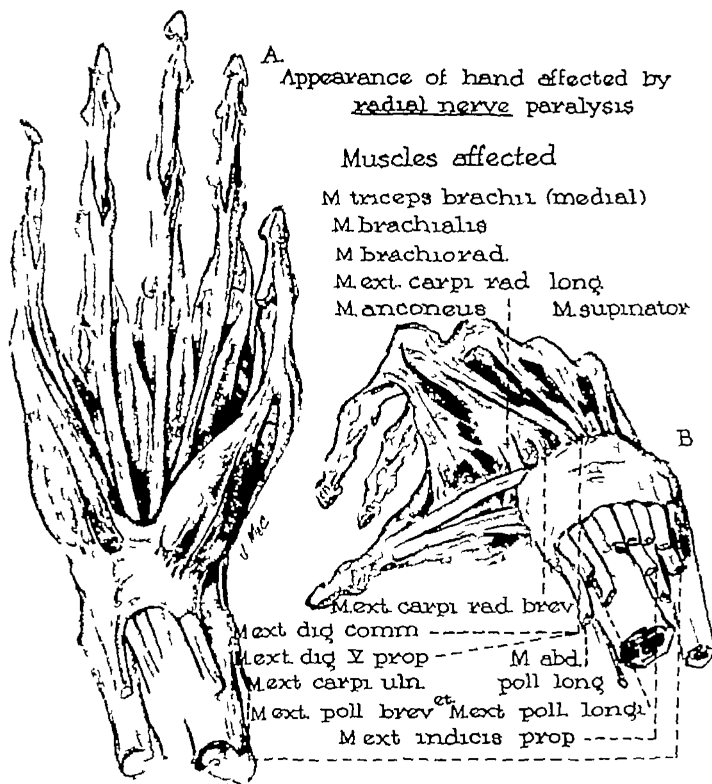

A.
Appearance of hand affected by
radial nerve paralysis
Muscles affected
M triceps brachii (medial)
M. brachialis
M brachiorad.
M. ext. carpi rad long.
M. anconeus
M. supinator
B
M. ext. carpi rad. brev
M ext. dig comm
M ext. dig V prop
M abd.
poll long
M ext carpi uln.
M ext. poll brev et M. ext poll. longi
M ext indicis prop

Figure 64.



Figure 65 Deep radial nerve paralysis showing the complete loss of the ability to extend the thumb and fingers. Adorsiflexion of wrist is maintained.



Figure 66 Deep radial nerve paralysis showing an attempt to extend the thumb and fingers.

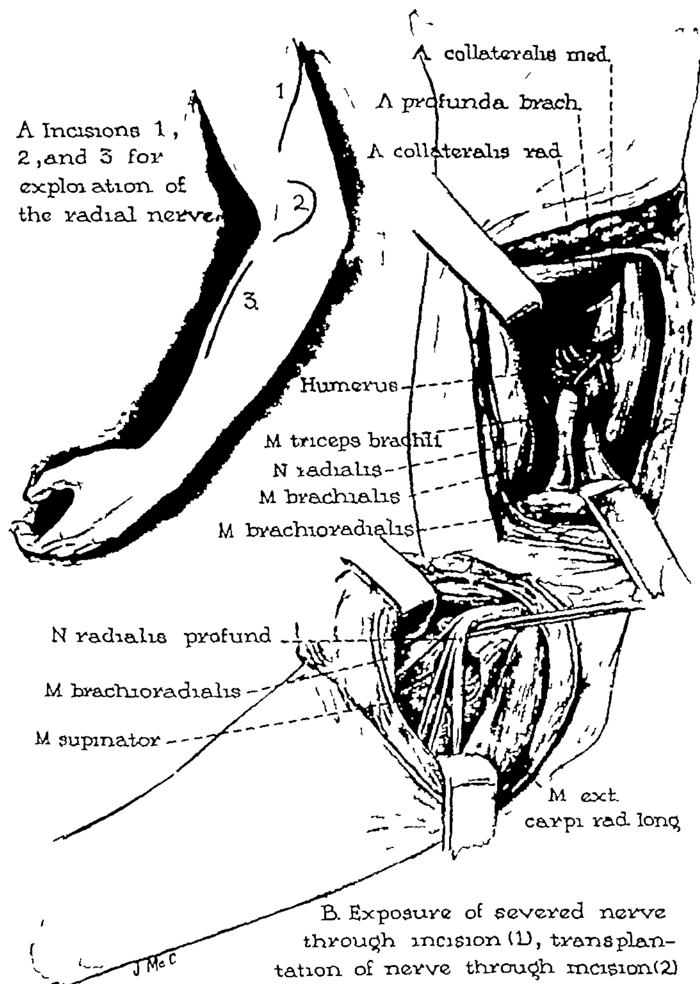

A Incisions 1, 2, and 3 for exploration of the radial nerve
1
2
3
A collateralis med.
A profunda brach.
A collateralis rad
Humerus
M triceps brachii
N radialis
M brachialis
M brachioradialis
N radialis profund
M brachioradialis
M supinator
M ext. carpi rad. long
B. Exposure of severed nerve through incision (1), transplantation of nerve through incision (2)
J McC

Figure 67

VIII

THE AXILLARY NERVE

The axillary nerve is primarily a motor nerve for raising the arm. Paralysis of this nerve while leaving the hand and forearm normal, renders the arm completely useless at the shoulder joint so that it hangs from the shoulder

ANATOMY

The axillary nerve is derived from the posterior cord of the brachial plexus and takes origin from the fifth and sixth cervical roots of the spinal cord. It lies behind the axillary artery *After leaving the axilla* it winds around the surgical neck of the humerus along with the posterior humeral circumflex artery, through the quadrilateral space and then divides into a small superior and larger inferior branch (Fig 76)

The superior branch supplies the deltoid while the inferior one goes to the teres minor muscle A cutaneous twig supplies a variable area of skin over the region of the lower portion of the deltoid

COURSE AND DISTRIBUTION

The axillary nerve supplies the deltoid and teres minor muscles (Fig 68)

TEST FOR MUSCLE FUNCTION AND INTACTNESS OF AXILLARY NERVE

Maintain abduction of arm against resistance

CHARACTERISTIC SYMPTOMS

Injury to the axillary nerve and para
of the deltoid muscle results in inabilit
raise the arm outward forward, and ba
ward. It is associated with atrophy of
deltoid muscle which results in the vis
marked flattening and slightly concave c
tour of the normal outer arm. The en
shoulder joint can be seen and palpated (
69 and 70) The acromion process beco
prominent and the head of the humerus
be palpated The integrity of the join
threatened by long standing deltoid paraly
Weak substitution movements are usu
developed by utilizing the pectoralis ma
supraspinatus serratus anterior and
pezius

SURGICAL ANATOMY

(*Figs 76 80C*)
Same as infraclavicular exposure

INCISION AND EXPOSURE

Incision and exposure same as for brach
plexus and infraclavicular incision althou
the axillary and radial nerves lie deep bene
the median and the cords of brachial plex
The anterior approach using the infraclav
ular approach to the plexus is the most s
isfactory for exposure and repair (Figs. 8
and 80C)

Musculocutaneous and axillary nerves
$C_5 - C_6$ $C_5 - C_6$

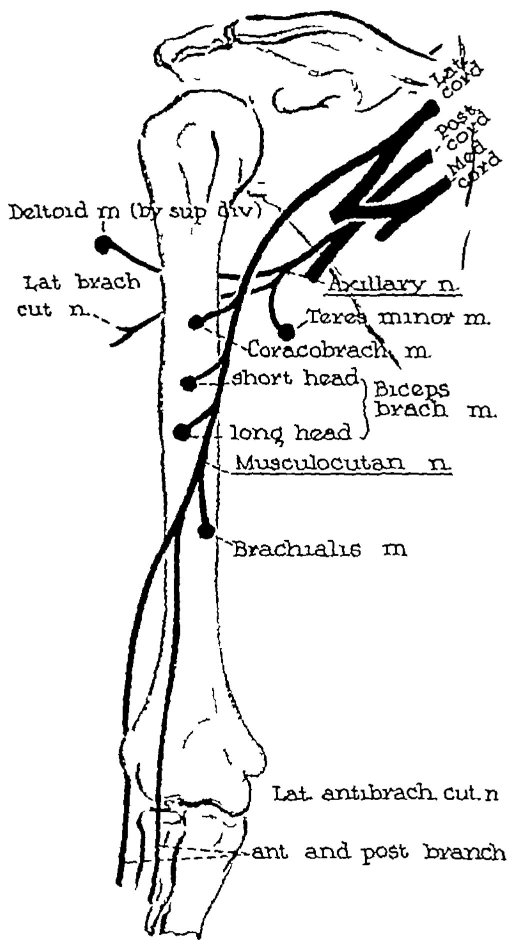


Figure 61 (Modified after Pitres and Testut LES NERFS EN SCHEMAS.)



Figure 69 Axillary and deltoid nerve paralysis.

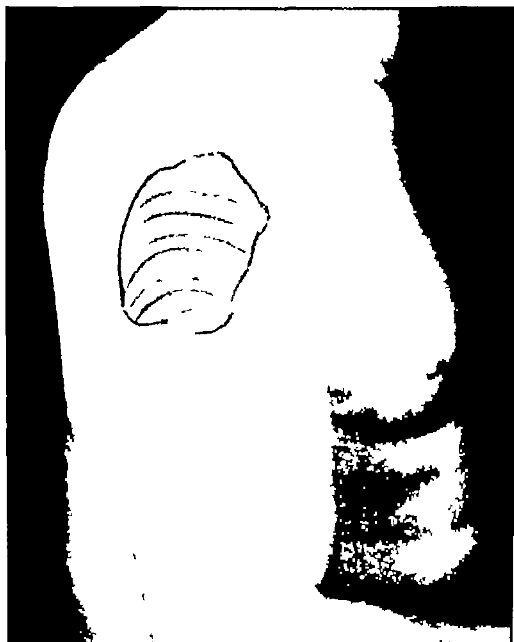


Figure 70 Axillary and deltoid nerve paralysis, showing sensory loss.

IX

THE MUSCULOCUTANEOUS NERVE

The musculocutaneous nerve is the nerve for bending the elbow Loss of function of this nerve would therefore be as serious a handicap as loss of the elbow joint

ANATOMY

The musculocutaneous nerve takes origin from the lateral cord of the brachial plexus Its fibers are derived from the fifth and sixth cervical roots of the spinal cord along with the outer head of the median It lies lateral to the axillary artery in the axilla, then lies adjacent to the median nerve and first part of the brachial artery It pierces the coraco brachialis The nerve becomes subcutaneous near the bend of the elbow and continues as the lateral antibrachial cutaneous nerve (of the forearm)

COURSE AND DISTRIBUTION

(Fig 68)

Musculocutaneous and axillary nerves.

Nerve Supplies Motor to biceps, brachialis and coracobrachialis, sensation to autero lateral surface of forearm.

TEST OF MUSCLE FUNCTION AND INTACTNESS OF MUSCULOCUTANEOUS NERVE

Flex forearm against resistance.

SYMPTOMS OF MUSCULOCUTANEOUS PARALYSIS

Paralysis of the biceps and brachialis (and coracobrachialis) results in loss of major power to flex the elbow

Weak flexion of the elbow may still be possible when the forearm is pronated by action of the brachioradialis which is innervated by the radial nerve Cutaneous sensation is lost over the anterolateral surface of the fore arm from the elbow to the wrist.

Injuries of the musculocutaneous alone are rare They are usually involved in the brachial plexus or along with the lateral head of median. A recent case was observed which was caused from pressure from massive callus of healed humerus.

SURGICAL ANATOMY

(Figs 76 80B and 80C)

INCISION FOR OPERATIVE EXPOSURE

(Figs 80B and 80C)

Infraclavicular approach to brachial plexus.

SURGICAL EXPOSURE

(Fig 80C)

Infraclavicular approach to brachial plexus.

X

THE SCAPULAR NERVES

The scapular nerves comprise the following

1. Dorsal scapular (C5)—The nerve to the rhomboides
2. The suprascapular (C4 C5, C6)—The nerve to the supraspinatus and infraspinatus muscles.
3. The thoraco-dorsal or long subscapular (C7, C8)—The nerve to the latissimus dorsi.
4. The subscapular (C5, C6)—The nerve to subscapularis and teres major muscles.

Injuries to the scapular nerves are rare They have been observed following a severe blow over the scapular region. They are found primarily along with brachial plexus injuries

XI

THE ANTERIOR THORACIC (*Pectoral*) NERVES

The anterior thoracic nerves comprise the medial and lateral anterior thoracic nerves

The medial anterior thoracic nerve (C8 T1) supplies mainly the pectoralis minor muscle

The lateral anterior thoracic nerve (C5 C6, C7) supplies the pectoralis major muscle

Injury to the anterior thoracic nerves are rare and are usually accompanied by injury to the brachial plexus. Diagnosis is made by atrophy of pectoralis muscles (Fig 71)

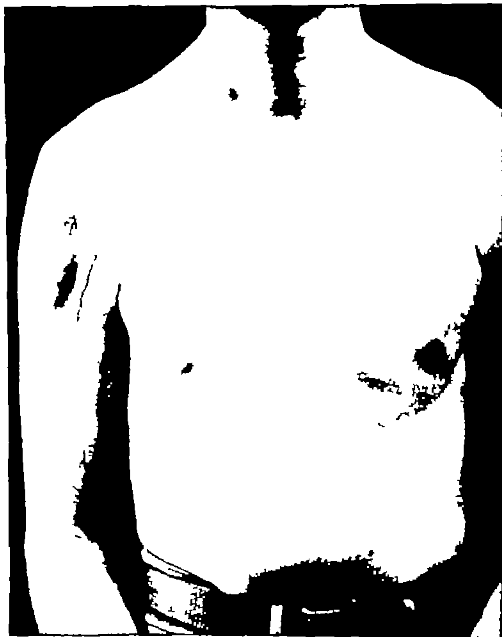


Figure 71 Atrophy of pectorales muscles resulting from injury to lateral anterior thoracic nerves.

XII

THE LONG THORACIC NERVE

The long thoracic nerve is the nerve that supplies the serratus anterior muscle the muscle for fixation of the vertebral border of the scapula. Paralysis of the long thoracic nerve results in winging of the scapula (Fig 72)

ANATOMY

The long thoracic nerve takes origin from the fifth, sixth and seventh cervical nerves. The origin is from the undivided antei primary rami near the vertebral forami The nerve descends behind the brach plexus and the axillary vessels, and supp each of the digitations of the serratus antei muscle The nerve is entirely motor Isola injuries of the long thoracic nerve are 1 common Although eight cases of long t racic nerve involvement were observed, o three were due to injuries



Figure 72 Long thoracic nerve paralysis with a winging of the scapula.

XIII

THE BRACHIAL PLEXUS

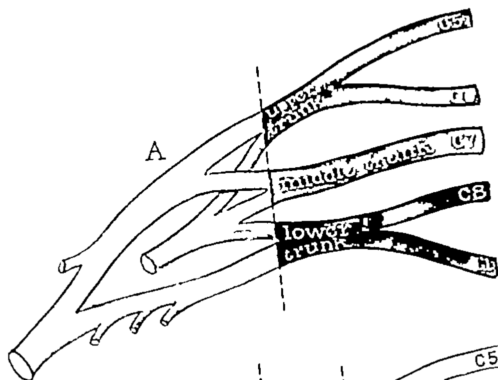
The brachial plexus supplies the musculature of the entire upper extremity, the shoulder girdle and the pectoral muscles A major injury to the brachial plexus results in a useless flail arm (Figs. 74 and 75) When inoperable, the arm is best removed though all other structures are intact, since the arm becomes a cumbersome, dead weight.

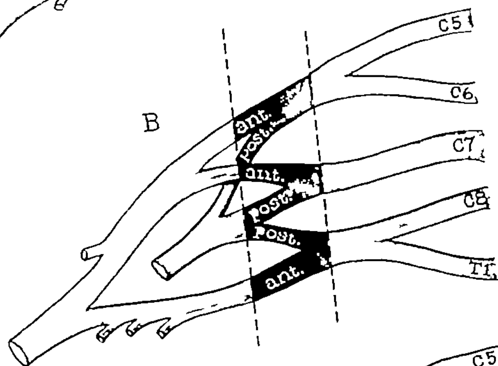
ANATOMY

The brachial plexus is formed from the anterior rami of C5 C6, C7 C8 and T1 *roots of the spinal cord These roots unite* near their point of origin The plexus thus formed extends from the lower part of the side of the neck to the axilla (Fig. 76)

The fifth and sixth cervical root form a trunk the eighth cervical thoracic unite to form a trunk seventh cervical runs out alone sults in the formation of three trunk middle and lower (Fig. 73A) T pass beneath the clavicle where ea divides into an anterior and poste sion (Fig 73B)

The anterior division of the u middle trunks unites to form the lat The anterior division of the low *continues alone as the medial c* three posterior divisions unite to posterior cord The medial and late unite to form the median nerve (F


A
upper trunk
C7
middle trunk
C8
lower trunk


B
C5
C6
C7
C8
T1
ant.
post.
ant.
post.
post.
ant.

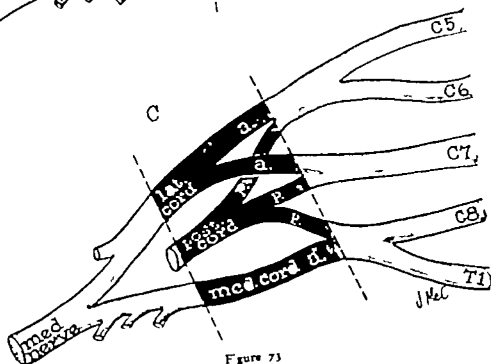

C
C5
C6
C7
C8
T1
a.
a.
lat. cord
p.
p.
p.
post. cord
med. cord
med nerve

Figure 73



Figure 74. A flail arm caused by a brachial plexus injury



Figure 75 Brachial plexus paralysis with complete paralysis of the hand and arm showing atrophy of the hand and fore arm.

COURSE AND DISTRIBUTION
(Figs 76 and 77)

TESTS OF MUSCLE FUNCTION
Considered under separate nerves

SURGICAL ANATOMY
(Fig 78)

INCISIONS FOR OPERATIVE EXPOSURE

The regions of the brachial plexus are divided into four portions for convenience of surgical approach in the neck beneath the pectoral muscles in the axilla, and in the clavicular region.

1 SUPRACLAVICULAR INCISION
For exploration of trunks of brachial plexus in the neck.

2 INFRACLAVICULAR INCISION
For exploration of cords of the plexus beneath pectoral muscles

3 TRANSCLAVICULAR INCISION
For exposing cords and secondary trunks of the brachial plexus above, below, and beneath the clavicle

4. TRANSVERSE AXILLARY INCISION
For exposing peripheral nerves after their origin from the brachial plexus in the axilla.

The Supraclavicular Incision This is a five to six centimeter transverse incision placed about two centimeters above, and parallel to the clavicle (Fig 79A) This incision is used to explore the roots of the brachial plexus in the region of the scaleni muscles. It is also used for surgery of the scalenus muscles. The surgical anatomy and opera

[1]Taylor A. S.: Brachial birth palsy *Lewis' Practice of Surgery* Hagerstown, Md., W F Prior Co Inc., 1932.

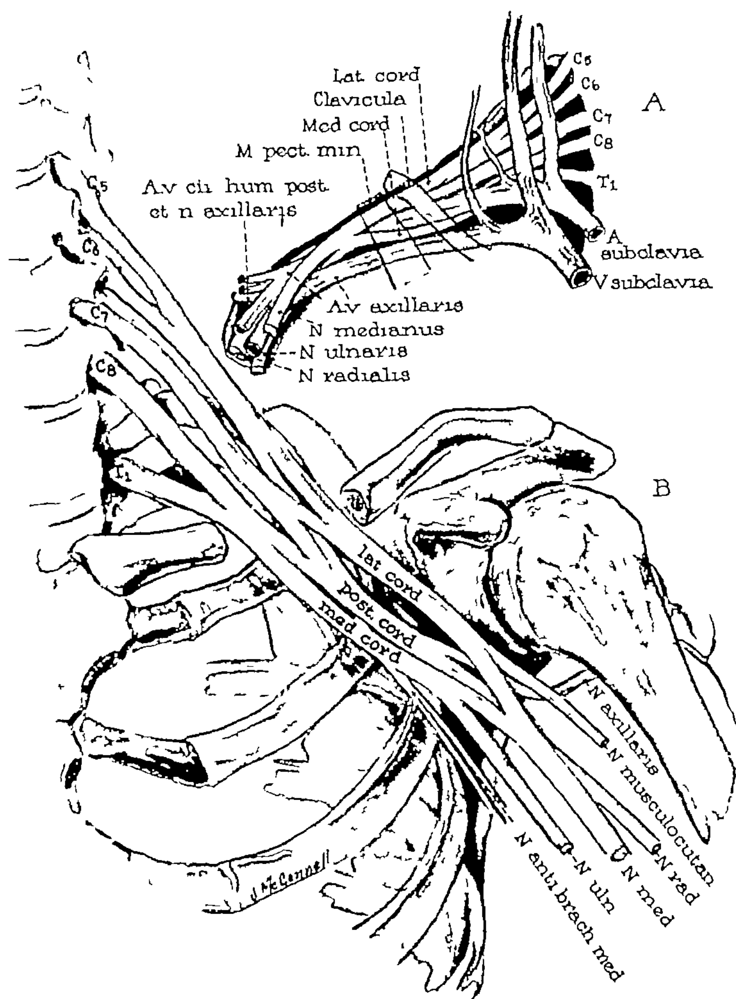

A
B
Lat. cord
Clavicula
Med cord
M pect. min
A.v cir hum post. et n axillaris
C5
C6
C7
C8
T1
A subclavia
V subclavia
A.v axillaris
N medianus
N ulnaris
N radialis
lat. cord
post. cord
med cord
N axillaris
N musculocutan
N rad
N med
N uln
N anti brach med
J McConnell

Figure 76

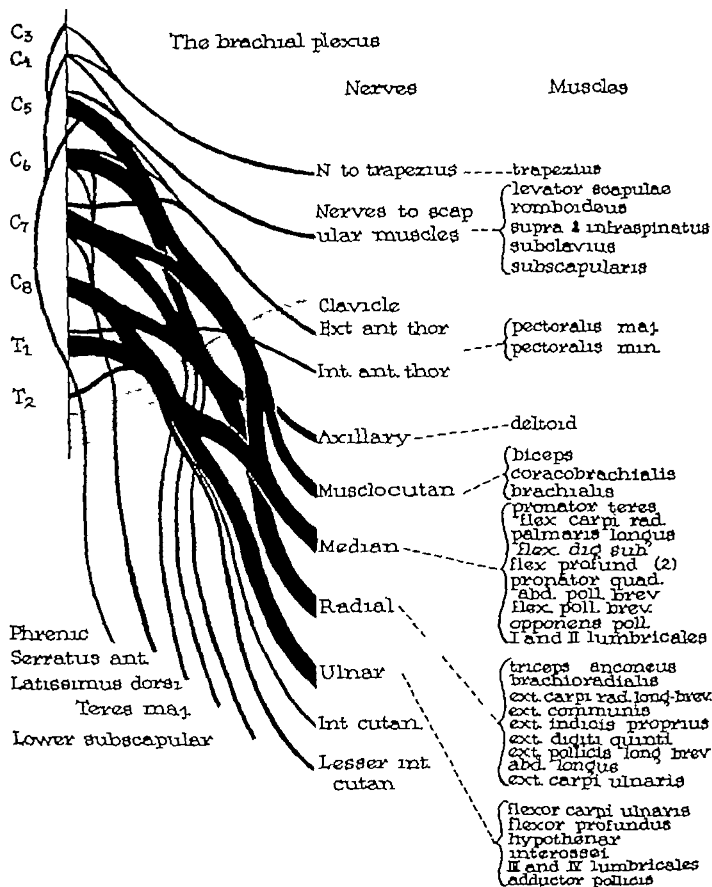


Figure 77 (After Meige, *CORRELATIVE NEUROANATOMY*)

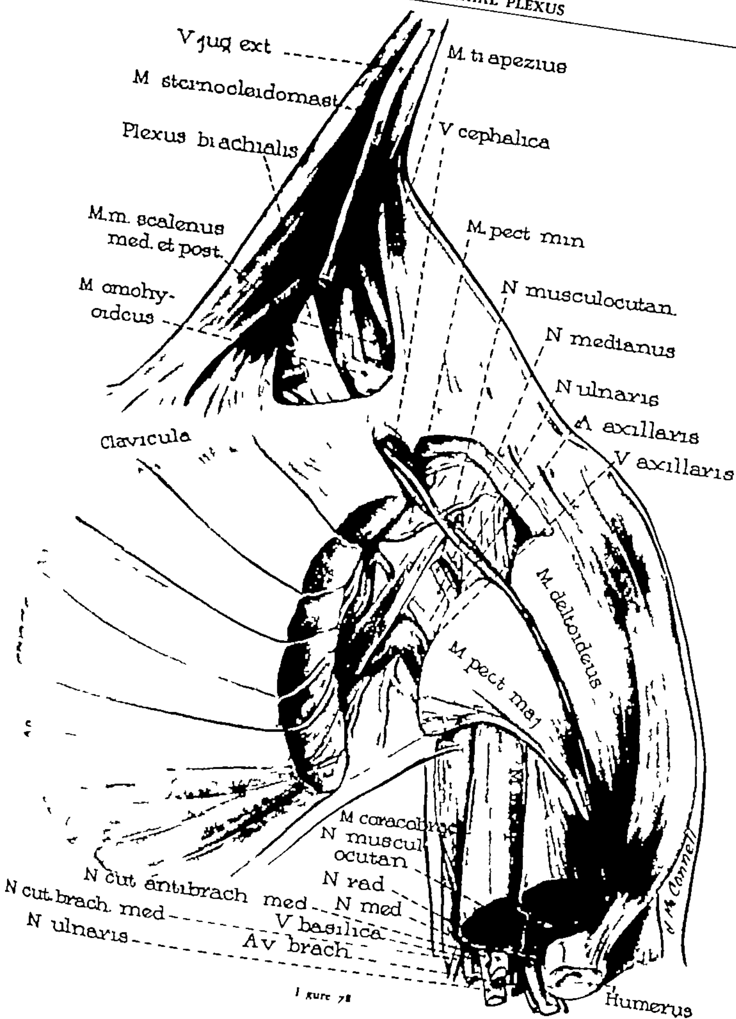

V jug ext
M sternocleidomast
Plexus brachialis
M.m. scalenus
med. et post.
M omohy-
oideus
Clavicula
M. trapezius
V cephalica
M. pect min
N musculocutan.
N medianus
N ulnaris
A axillaris
V axillaris
M. deltoideus
M pect maj
M coracobrac
N muscul
ocutan
N rad
N med
V basilica
A v brach
N cut antibrach med
N cut. brach. med
N ulnaris
Humerus
McConnell

Figure 78

tive exposure is shown in Fig 79B A cross section of the anatomy of the neck is shown in Fig. 79C.

The Infraclavicular Incision This is the accepted approach for exposure of the cords of the brachial plexus beneath the pectoralis major and minor muscles. It consists of a transverse incision beginning some five centimeters below the clavicle and continuing lateralward into the arm over the region of insertion of the pectoralis major muscle as shown in Fig 80B The pectoral muscle is exposed and split in the direction of its fibers bringing the roots of the brachial plexus into view (Fig 80C)

Operative exposure in the infraclavicular incision is shown in Fig 80C. Cross section anatomy of the infraclavicular region is shown in Fig 80A.

Transclavicular Incision to Brachial Plexus [8] By this approach the brachial plexus from the three primary trunks to their division into lateral, medial, and posterior cord, may be exposed above, beneath, and below the clavicle without sacrificing the clavicle or without injury to the fibers of the pectoralis major muscle A modified semi circular incision is made beginning above the clavicle near its sternal attachment, and continuing upward and lateralward to the border of the deltoid muscle (Fig 81A Part 1) The incision now curves downward and crosses the clavicle at its outer third (Fig 81A Part 2) It is now continued downward toward the axilla (Fig 81A, Part 3) When the skin flap is retracted the fascial plane between the deltoid and pectoralis major muscle is clearly discernible (Fig 78) The clavicle is divided at this point (Fig 81A, Part 2) The lateral portion is retracted upwards and the medial portion, with the pectoralis major attached, is retracted downward and outward (Fig 81B) The pectoral muscle is in this way separated from the deltoid in its normal plane of cleavage bringing the entire brachial plexus clearly into view (Fig 81B) At the termination of the surgical procedure, the clavicle is wired together This procedure surpasses all other clavicular approaches to the brachial plexus in that the integrity of the shoulder girdle is more easily maintained. Operative exposure of the transclavicular approach is shown in Fig 81B

Transverse Axillary Incision All the nerves of the upper extremity may be exposed through the transverse axillary incision.[9] This incision follows a flexion crease across the entire axilla as shown in Fig. 17 The anatomy of the brachial plexus in the region of the axilla is shown in Fig 83 This is the incision of choice especially for exposing the radial nerve, since it lies posteriorly in the axilla. Such an incision avoids the deformity and disability of a traction scar which follows an incision perpendicular to the flexion crease in the axilla.

SURGICAL EXPLORATION

(Fig 82C)

CROSS SECTION

(Fig 82B)

---

[8] Stone, C. S., J Transclavicular approach to brachial plexus. Personal communication to the author

[9] McCravey A gustus Transverse axillary incision for exploration of brachial plexus. Personal communication to the author

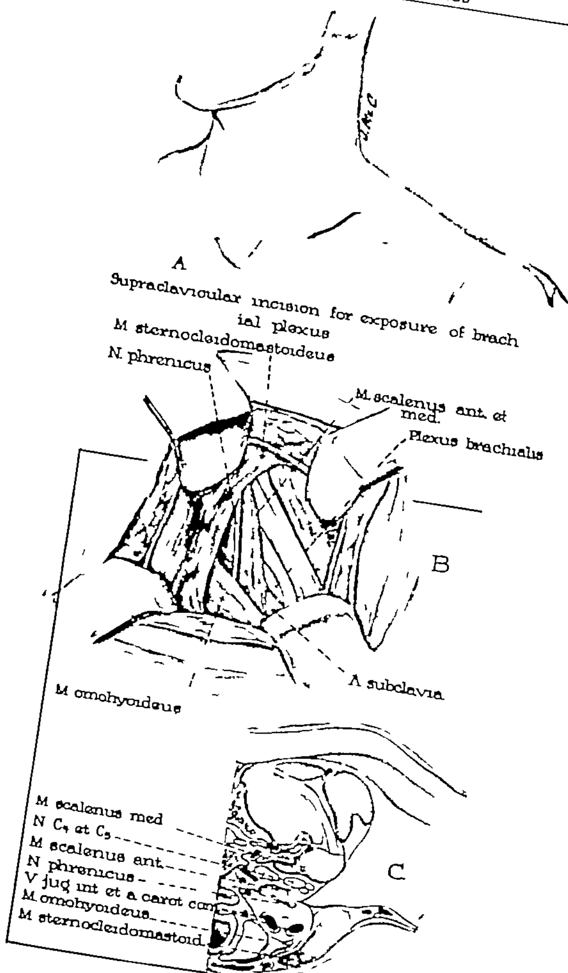

A
Supraclavicular incision for exposure of brachial plexus
M sternocleidomastoideus
N. phrenicus
M. scalenus ant. et med.
Plexus brachialis
B
A subclavia
M omohyoideus
M scalenus med
N C4 et C5
M scalenus ant.
N phrenicus
V jug int et a carot com
M. omohyoideus
M sternocleidomastoid
C

Figure 79

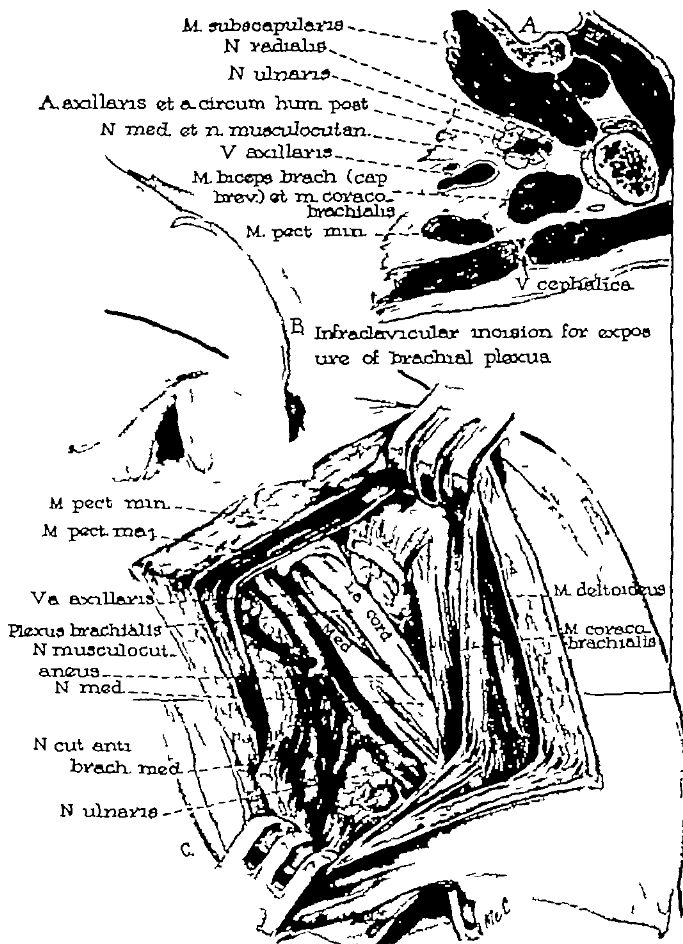
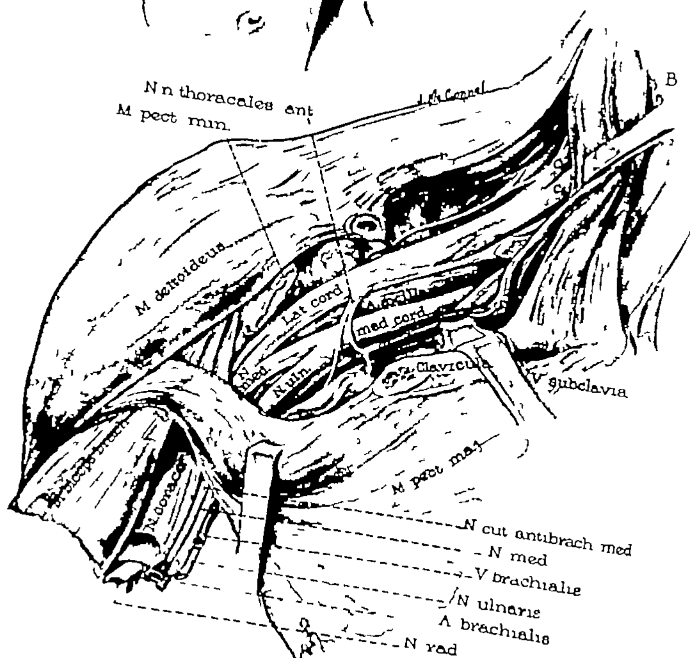

M. subscapularis
N radialis
N ulnaris
A. axillaris et a. circum hum. post
N med. et n. musculocutan.
V axillaris
M. biceps brach (cap brev.) et m. coraco-brachialis
M. pect min.
A
V cephalica
B
Infraclavicular incision for exposure of brachial plexus
M pect min.
M pect. maj
Va axillaris
Plexus brachialis
N musculocut-aneus
N med.
N cut anti brach. med.
N ulnaris
C.
La cord
Med
M. deltoideus
M coraco-brachialis
McC

Figure 8a.



Transclavicular approach to plexus
A
1
2
3
Clavicula cut on slant
B
N n thoracales ant
M pect min.
M deltoideus
Lat cord
med cord
N med.
N uln.
Clavicula
V subclavia
N thoracal
M pect maj
N cut antibrach med
N med
V brachialis
N ulnaris
A brachialis
N rad

Figure 81

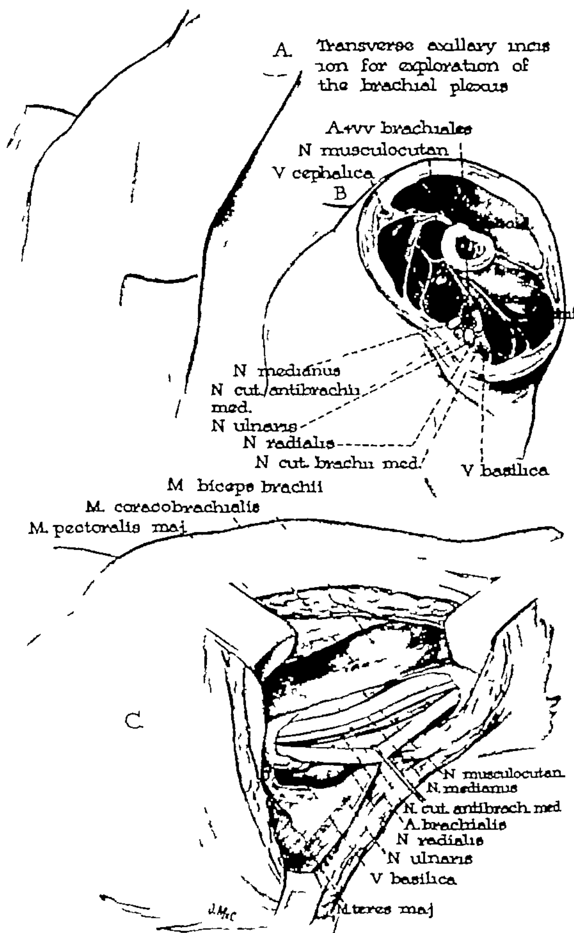

A. Transverse axillary incision for exploration of the brachial plexus
A+vv brachiales
N musculocutan
V cephalica
B
N medianus
N cut. antibrachii med.
N ulnaris
N radialis
N cut. brachii med.
V basilica
M biceps brachii
M. coracobrachialis
M. pectoralis maj
C
N musculocutan.
N. medianus
N. cut. antibrach. med
A. brachialis
N radialis
N ulnaris
V basilica
M. teres maj

Figure 81

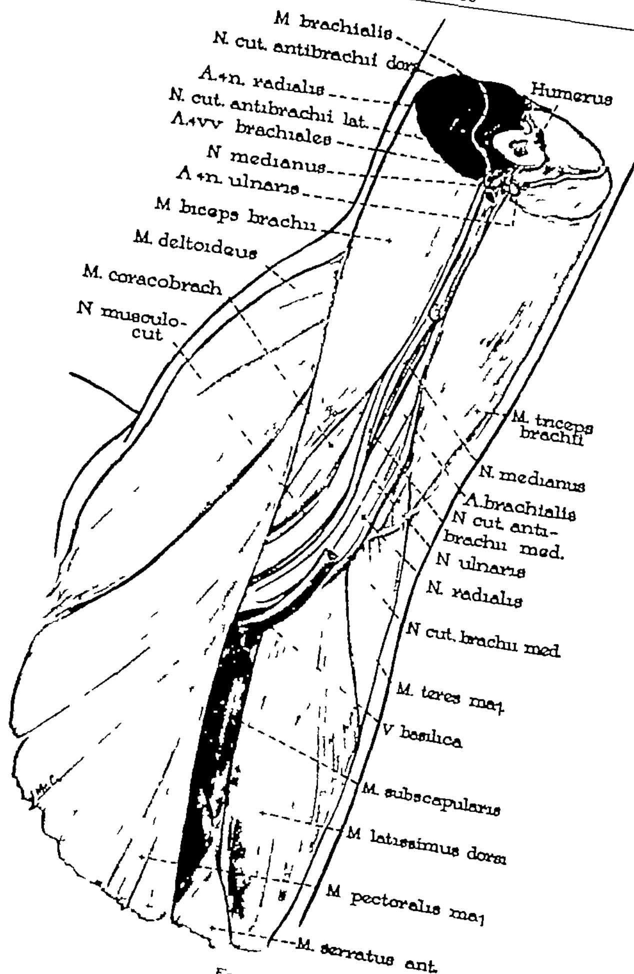

M brachialis
N. cut. antibrachii dors
A.+n. radialis
N. cut. antibrachii lat.
A.+vv brachiales
N medianus
A +n. ulnaris
M biceps brachii
M. deltoideus
M. coracobrach
N musculo-cut
Humerus
M. triceps brachii
N. medianus
A. brachialis
N cut. antibrachii med.
N ulnaris
N. radialis
N cut. brachii med
M. teres maj.
V basilica
M. subscapularis
M latissimus dorsi
M pectoralis maj
M. serratus ant.

Figure 83

XIV

THE FEMORAL NERVE

The femoral nerve is the nerve for extension of the leg It supplies the anterior group of thigh muscles (*quadriceps femoris*) Paralysis of the femoral nerve causes loss of ability to extend the leg at the knee Atrophy of the thigh results (Figs. 84 and 85) Walking forward is difficult in femoral nerve paralysis the loss of function being the same as in laceration of the patellar tendon or fracture and separation of the patella. Most of the femoral nerve injuries observed were in perforating wounds of the groin and lower abdomen.

Of the 2 037 peripheral nerve injuries studied, 41 were of the femoral nerve

ANATOMY

The femoral nerve is the largest branch of the lumbar plexus and its roots of origin are from the second third and fourth lumbar roots of the spinal cord It courses downward passing through the psoas major muscle then between the psoas and iliacus muscles beneath the inguinal ligament into the thigh (Fig 87B)

COURSE AND DISTRIBUTION

a. Diagram (Fig 86)
b Motor and Sensory Supply

MOTOR

Abdomen—iliacus

Thigh { quadriceps femoris { rectus femoris, vastus medialis, vastus lateralis, vastus intermedius }; sartorius }

SENSORY

Cutaneous sensation is to the anterior and medial surface of the thigh and leg (Fig 85)

SURGICAL ANATOMY

(Fig 87B)
Incision for operative exposure in the pelvis (Fig 87A)

TESTS OF MUSCLE FUNCTION AND THE INTACTNESS OF THE FEMORAL NERVE

NERVE	MUSCLE	TEST
femoral L2, 3	iliacus	with knee flexed and leg supported, hip is flexed just beyond 90 degrees. Patient now tries to flex hip against resistance
femoral nerve L2 L3 L4	sartorius	with patient on back and with hip laterally rotated flex knee against resistance and muscles can be felt just below groin
femoral nerve L2 L3 L4	quadriceps femoris	extend knee against resistance



Figure 84. Left femoral nerve paralysis with atrophy of the quadriceps muscles of the left thigh.

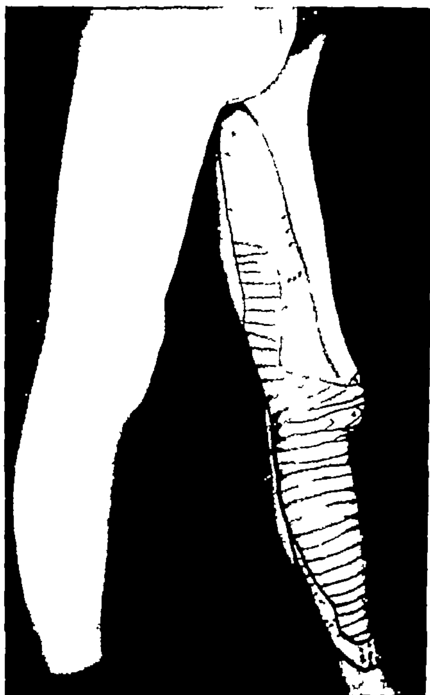


Figure 85 Muscle atrophy and sensory loss in femoral nerve paralysis.

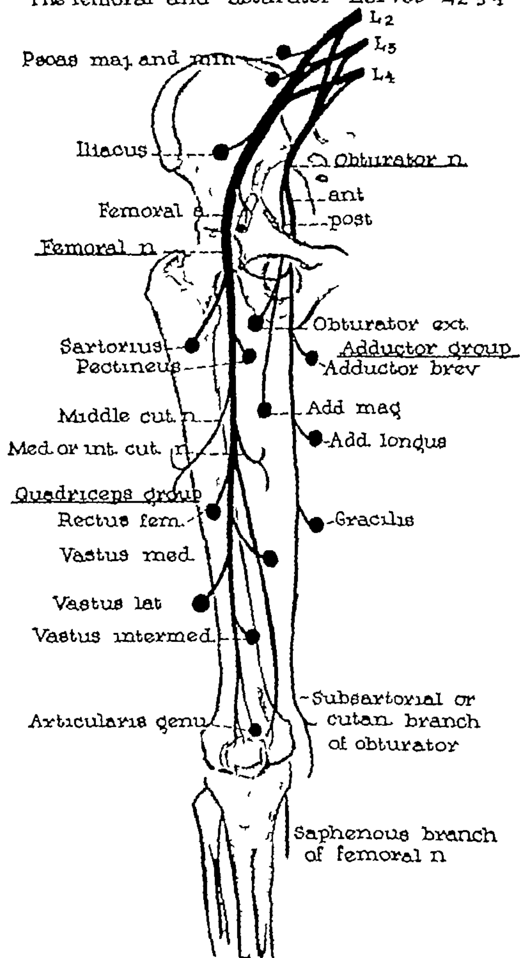
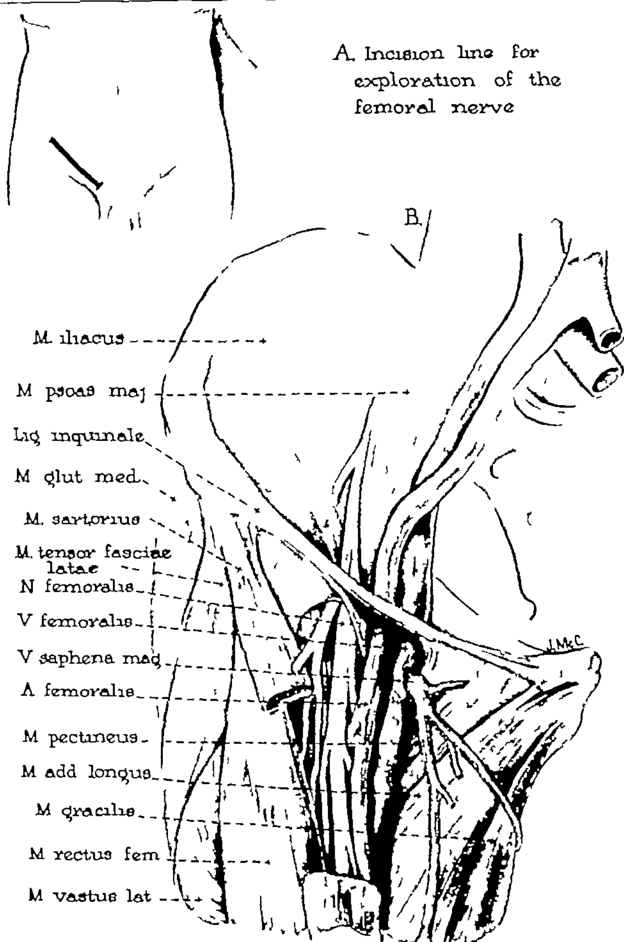

The femoral and obturator nerves L2 3-4
L2
L3
L4
Psoas maj. and min
Iliacus
Obturator n.
ant
post
Femoral a.
Femoral n
Obturator ext.
Adductor group
Sartorius
Pectineus
Adductor brev
Add mag
Middle cut. n
Med. or int. cut. n
Add. longus
Quadriceps group
Rectus fem.
Gracilis
Vastus med.
Vastus lat
Vastus intermed.
Subsartorial or
cutan. branch
of obturator
Articularis genu
Saphenous branch
of femoral n

Figure 26



A. Incision line for exploration of the femoral nerve
B.
M. iliacus
M psoas maj
Lig inguinale
M glut med.
M. sartorius
M. tensor fasciae latae
N femoralis
V femoralis
V saphena mag
A femoralis
M pectineus
M add longus
M gracilis
M rectus fem
M vastus lat
J.McC.

Figure 87

XV

THE SCIATIC NERVE

The sciatic nerve is responsible for the innervation of the entire lower extremity The only exception is the supply to the quadriceps muscles which is by the femoral nerve

The sciatic nerve is the largest nerve in the human body It is the continuation of the sacral plexus, and is analogous in its importance to the lower extremity as is the brachial plexus to the upper extremity

Bilateral sciatic injury renders the patient almost as helpless as does injury to the spinal cord. It was no uncommon practice in the past to amputate the limb in instances of sciatic nerve paralysis.

In the author's series of 2037 nerve injuries, 120 were sciatic.

ANATOMY

The sciatic nerve is derived from fusion of fibers of L4 L5, S1, S2, and S3 roots (Fig 88) It passes out of the pelvis through the great sciatic foramen below the piriformis muscle It descends between the greater trochanter of the femur and tuberosity of the ischium and along the back of the thigh to the lower third where it divides into the posterior tibial and common peroneal nerves (Fig 89)

The sciatic nerve supplies the muscles of the back of the thigh, all the muscles of the leg and foot, and nearly the whole of the skin of the leg (Fig 90)

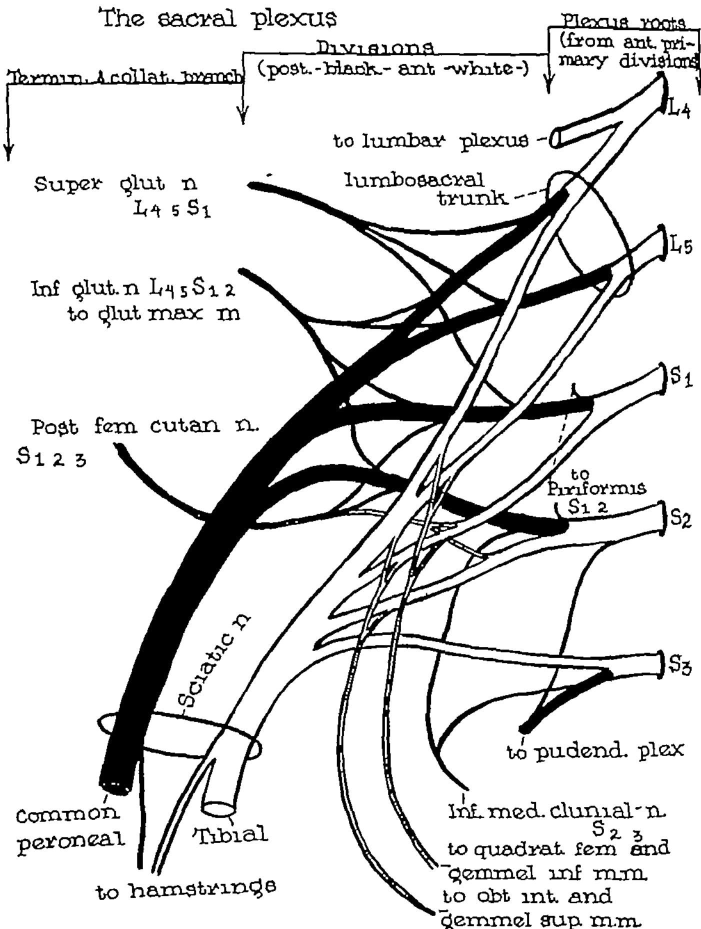
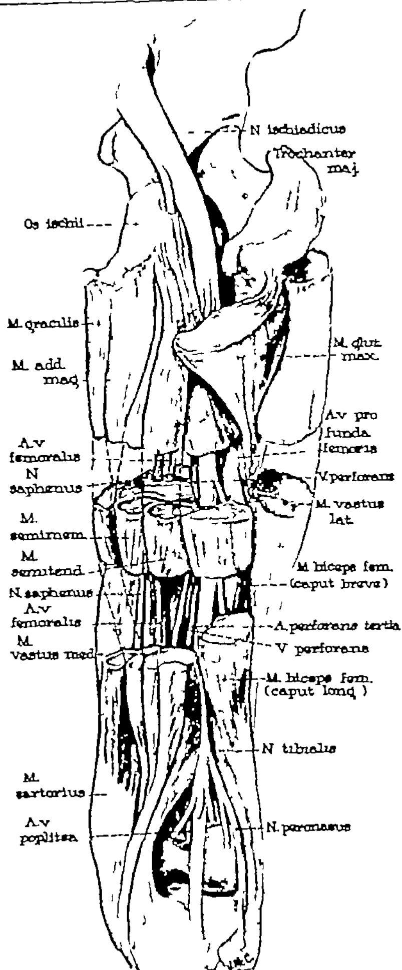


Figure 11 (Modified after McDonald Green and Lange *CORRELATIVE NEUROANATOMY*)



N ischiadicus
Trochanter maj.
Os ischii
M. gracilis
M. glut. max.
M. add. mag.
A.v. pro funda femoris
A.v femoralis
N saphenus
V. perforans
M. vastus lat.
M. semimem.
M. semitend.
M. biceps fem. (caput breve)
N saphenus
A.v femoralis
A. perforans tertia
M. vastus med.
V perforans
M. biceps fem. (caput long.)
N tibialis
M. sartorius
A.v poplitea
N. peronaeus

COURSE AND DISTRIBUTION

a. Diagram (Fig 90)
b Motor and Sensory Supply

MOTOR

Gluteus maximus (lesser sciatic)

From *main* sciatic trunk — hamstrings:
- semimembranosus
- *semitendinosus*
- biceps femoris
- adductor magnus

Tibial and Peroneal:
- gastrocnemius
- tibialis posterior
- flexor digitorum longus
- flexor hallucis longus
- tibialis anterior
- extensor digitorum longus
- extensor digitorum brevis
- peroneus longus
- peroneus brevis

SENSORY

Sensation to entire back of leg and dorsum and plantar surface of foot (Figs. 91 and 92)

TESTS OF MUSCLE FUNCTIONS AND INTACTNESS OF SCIATIC NERVE

Nerve	Muscle	Test
sciatic, L4 L5 S1 2–3	hamstrings	with patient on face, flex knee against resistance
sciatic, S1 and 2	gastrocnemius	with patient on face, plantar flex foot against resistance
sciatic, L5 and S1	tibialis posterior	invert foot against resistance

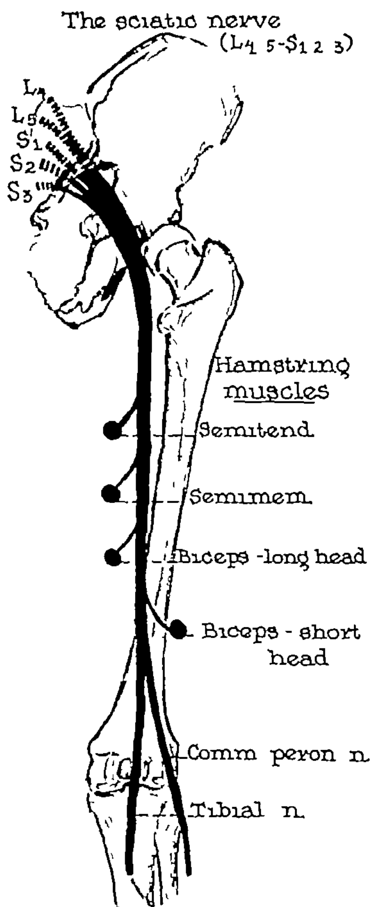

The sciatic nerve
(L4 5-S1 2 3)
L4
L5
S1
S2
S3
Hamstring muscles
Semitend.
Semimem.
Biceps -long head
Biceps - short head
Comm peron n.
Tibial n.

Figure 90.



Figure 91 Sciatic nerve paralysis showing atrophy of muscles and sensory loss.

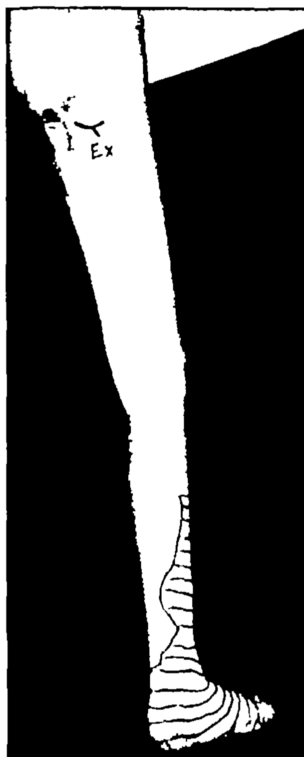


Figure 92. Sciatic nerve paralysis, showing atrophy of mus cles and sensory loss at the wound of exit

LEVEL OF LESION AND CHARACTERISTIC SYMPTOMS

Injuries of the great sciatic trunk result in paralysis of the hamstring muscles with loss of flexion of the leg at the knee joint

Lesions in the upper or middle third of the thigh as well as partial lesions may spare the semimembranosus and semitendinosus, and thereby preserve flexion of the leg There is also paralysis of all the muscles of the leg and foot with loss of plantar flexion dorsi flexion, and loss of movement of toes Sensory loss includes the outer side of the leg (*peroneal*), the entire foot (*tibial*), except the mesial surface, including the region of the internal malleolus (*saphenous*) Pain (*causalgia*) is often present over the tibial distribution in incomplete tibial paralysis Marked atrophy and dependent edema of the leg and especially the foot is often present. In incomplete lesions of the sciatic the peroneal component is more frequently involved.

SURGICAL ANATOMY

(*Fig* 89)

INCISIONS FOR OPERATIVE EXPOSURE OF SCIATIC NERVE

1 Exposure of the sciatic trunk.
2 Exposure of the sciatic nerve at the sciatic notch.
3 Exposure of sciatic nerve at the gluteal fold
4. Lateral approach to the sciatic nerve in the thigh.
5 Exposure of the sciatic nerve i popliteal region.

Exposure of the Sciatic Trunk.

Exposure of the sciatic nerve benea gluteal muscles is accomplished by usi sickle shaped incisions of Stookey[1] (Fig. A curved incision is made beginning mid gluteal region at the level of the iliac joint and continuing downwar outward over the greater trochanter femur The incision now curves dow and inward along the gluteal fold to th thigh. It now continues downward alo mid thigh for about five or six centi (Fig 93A Parts, 1, 2 and 3) The g maximus muscle is now split along the of its fibers all the way to the ten insertion at the iliotibial band over the of the greater trochanter The tendino sertion of the gluteus maximus muscle severed and the entire muscle is ref medialwards. By this exposure the nerv be explored from its exit at the sciatic to the gluteal fold (Fig 95)

Exposure of the Sciatic Nerve at the S Notch For convenience the Stooke cision is divided into three parts (Fig Part 1[1] is used to expose the sciatic ne the sciatic notch. Fig 94 shows the tive exposure of this incision.

Exposure of the Sciatic Nerve at the teal Fold Part 3 in Fig 93A illustrates t posing and repairing of the sciatic ne the gluteal fold When this incision al used only a small portion of the glute tachment is severed (Fig. 93B)

---

[1]Stookey B Surgery f the Nerves. *Loose Leaf Surgery* New York, T Nelson nd Sons, 9 7

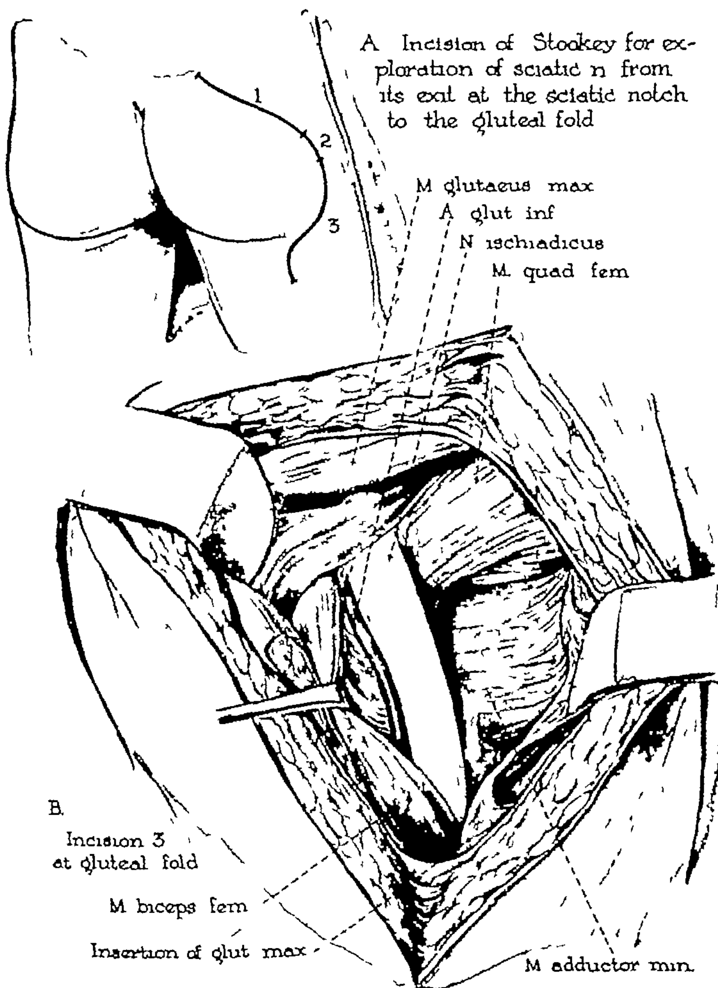

A Incision of Stookey for exploration of sciatic n from its exit at the sciatic notch to the gluteal fold
1
2
3
M glutaeus max
A glut inf
N ischiadicus
M. quad fem
B.
Incision 3 at gluteal fold
M biceps fem
Insertion of glut max
M adductor min.

Figure 93

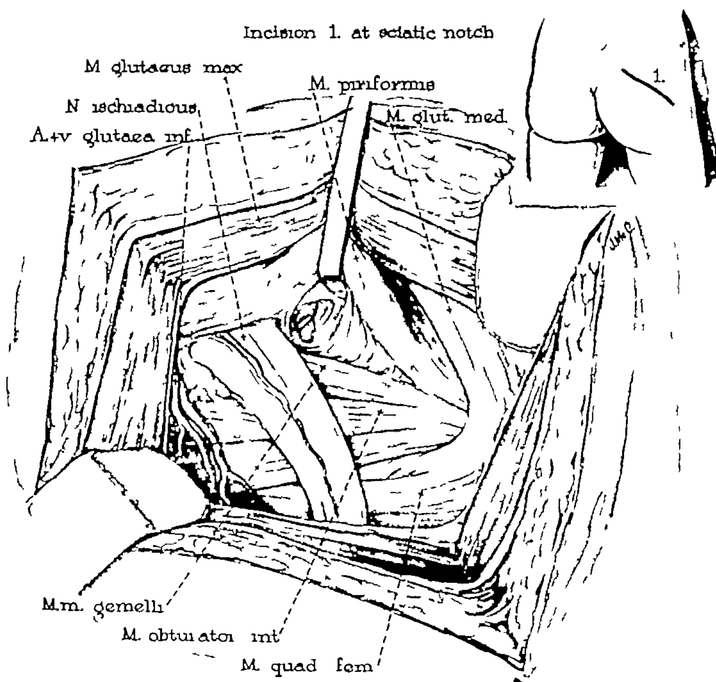

Incision 1. at sciatic notch
M glutaeus max
M. piriformis
N ischiadicus
M. glut. med.
A+v glutaea inf.
1.
M.m. gemelli
M. obturator int
M. quad fem

Figure 94.

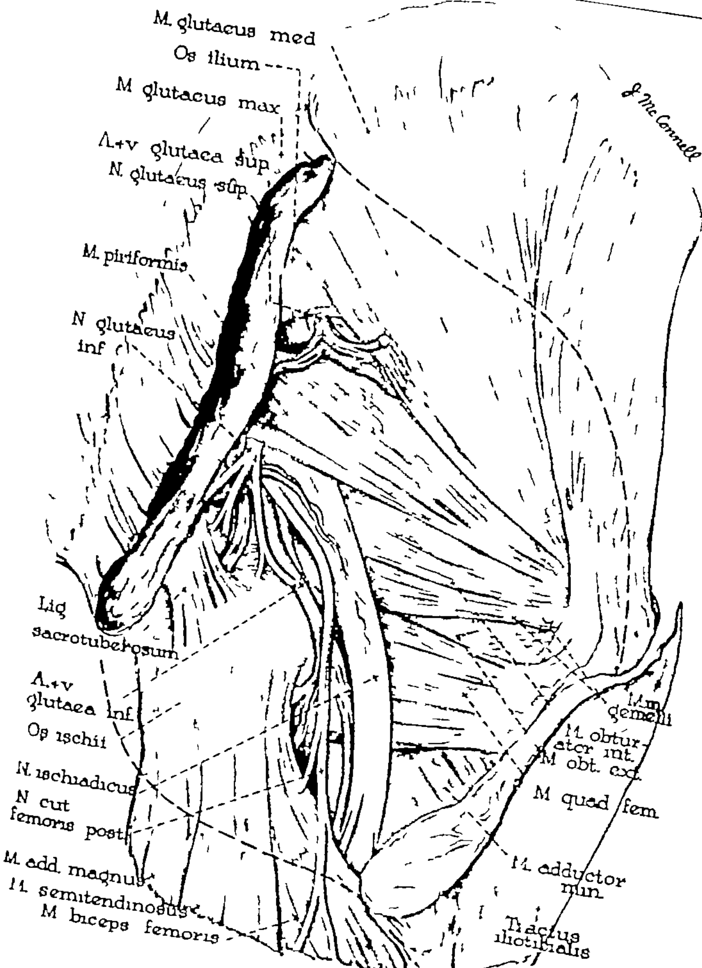

M. glutaeus med
Os ilium
M glutaeus max
A.+v glutaea sup
N. glutaeus sup
M. piriformis
N glutaeus inf
Lig sacrotuberosum
A.+v glutaea inf
Os ischii
N. ischiadicus
N cut femoris post
M. add. magnus
M. semitendinosus
M biceps femoris
Mm gemelli
M. obturator int.
M obt. ext.
M quad fem
M. adductor min.
Tractus iliotibialis
J. McConnell

Figure 95

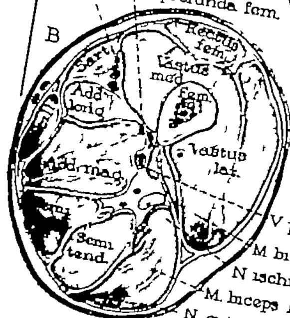
Lateral Approach to the Sciatic Nerve in the Thigh The sciatic nerve in the thigh is best exposed through a lateral incision This is a longitudinal incision placed in the plane of division between the vastus lateralis and biceps femoris muscles (Fig 96A)

A review of the anatomy of the sciatic nerve in the thigh (Fig 97) reveals that the massive biceps femoris muscle crosses the sciatic nerve in the middle third of the thigh from mesialward to lateralward This is easily understood since the muscle originates from the ischial tuberosity while the insertion is over the head of the fibula and lateral condyle of the tibia

The sciatic nerve below the level of the gluteal fold lies beneath the lateral border of the biceps femoris muscle in the upper two thirds of the posterior thigh rather than in the midline between the biceps and semitendinosus muscles. When the accepted midline incision is used along the posterior surface of the thigh, the biceps femoris muscle must be separated from both the semimembranosus and the semitendinosus muscles before the nerve can be exposed and in addition it will often be necessary to sever part of the attachment of the biceps muscle from the ischial tuberosity before the upper portion of the sciatic near the gluteal fold is adequately exposed The lateral incision is therefore a longitudinal incision placed in the plane of division between the vastus lateralis and biceps femoris muscles (Fig. 96A) The sciatic nerve is easily exposed when the biceps muscle is gently elevated and retracted mesiad (Fig 96C) A cross section of the thigh in its middle third is shown in Fig 96B

A Lateral approach to sciatic nerve

M. glut max.
N ischiadicus
M biceps fem. (cap long.)
M vastus lat.
M. biceps fem. (cap. breve)



C. Exposure of injured sciatic n.

Figure 96

Lateral Approach to the Sciatic Nerve in the Thigh The sciatic nerve in the thigh is best exposed through a lateral incision This is a longitudinal incision placed in the plane of division between the vastus lateralis and biceps femoris muscles (Fig 96A)

A review of the anatomy of the sciatic nerve in the thigh (Fig 97) reveals that the massive biceps femoris muscle crosses the sciatic nerve in the middle third of the thigh from mesialward to lateralward This is easily understood since the muscle originates from the ischial tuberosity, while the insertion is over the head of the fibula and lateral condyle of the tibia.

The sciatic nerve below the level of the gluteal fold lies beneath the lateral border of the biceps femoris muscle in the upper two thirds of the posterior thigh, rather than in the midline between the biceps and semitendinosus muscles When the accepted midline incision is used along the posterior surface of the thigh, the biceps femoris muscle must be separated from both the semimembranosus and the semitendinosus muscles before the nerve can be exposed and in addition, it will often be necessary to sever part of the attachment of the biceps muscle from the ischial tuberosity before the upper portion of the sciatic near the gluteal fold is adequately exposed The lateral incision is therefore a longitudinal incision placed in the plane of division between the vastus lateralis and biceps femoris muscles (Fig 96A) The sciatic nerve is easily exposed when the biceps muscle is gently elevated and retracted mesiad (Fig 96C) A cross section of the thigh in its middle third is shown in Fig 96B.

A. Lateral approach to sciatic nerve

M glut max

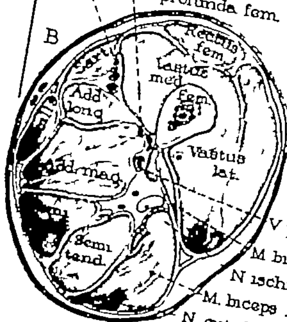
N ischiadicus

M biceps fem (cap long)

M vastus lat.

N saphenus + A.v femoralis

A.v profunda fem.



V perforans

M bic fem (cap brev)

N ischiadicus

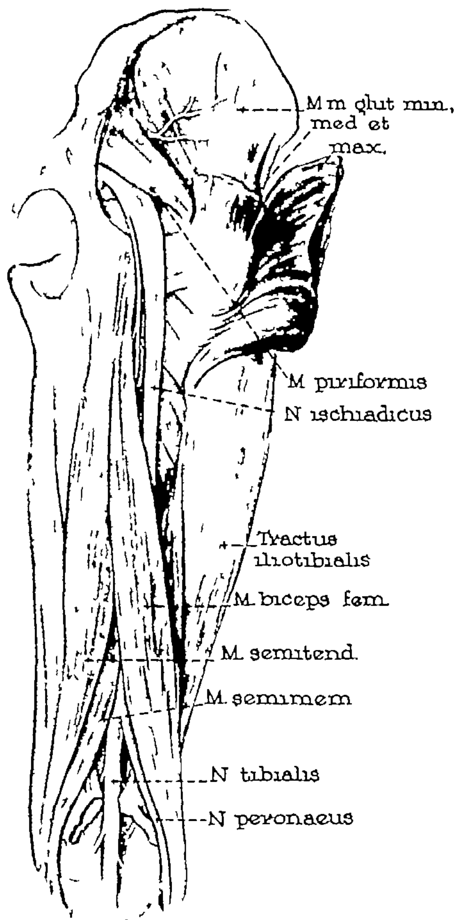
M. biceps fem. (cap long)

N cut fem post.

M. biceps fem. (cap breve)

C. Exposure of injured sciatic n.

Figure 96



M m glut min, med et max.
M piriformis
N ischiadicus
Tractus iliotibialis
M. biceps fem.
M. semitend.
M. semimem
N tibialis
N peronaeus

Figure 97

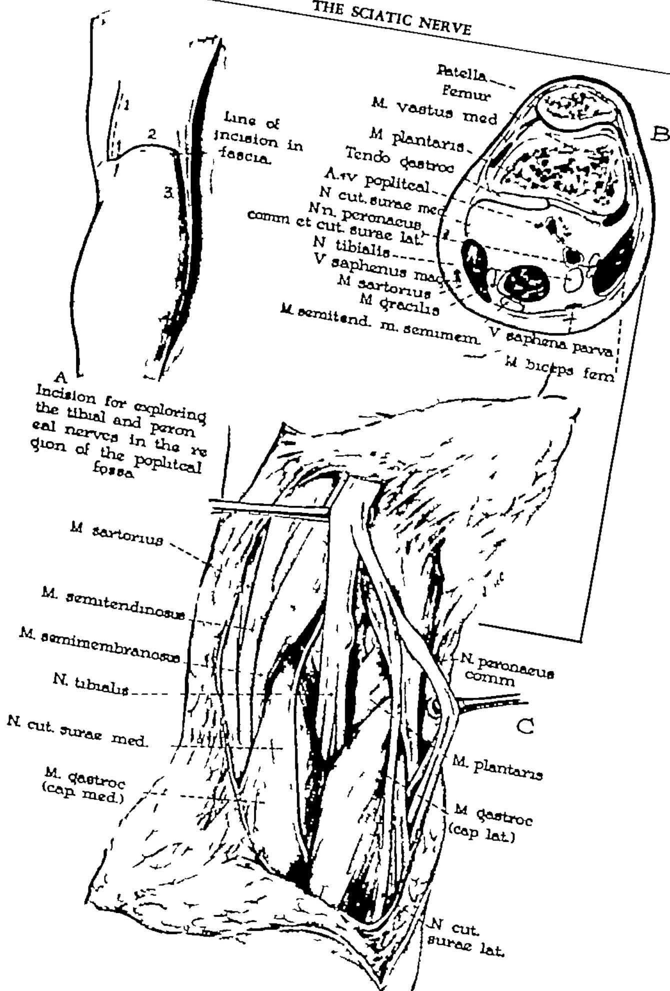

Line of incision in fascia.
1
2
3
A
Incision for exploring the tibial and peroneal nerves in the region of the popliteal fossa
Patella
Femur
M. vastus med
M plantaris
Tendo gastroc
A.v popliteal
N cut. surae med
Nn. peronaeus comm et cut. surae lat.
N tibialis
V saphenus mag
M sartorius
M gracilis
M semitend. m. semimem.
V saphena parva
M biceps fem
B
M sartorius
M. semitendinosus
M. semimembranosus
N. tibialis
N cut. surae med.
M. gastroc (cap. med.)
N. peronaeus comm
C
M. plantaris
M gastroc (cap lat.)
N cut. surae lat.

Figure 98

Exposure of Sciatic Nerve in the Popliteal Region The incision for exposure of the sciatic nerve in the popliteal region is divided into three parts (Fig 98A)

Part 1 is a longitudinal incision made along the posterior surface of the thigh in its lower third. This incision is carried down to, but not through, the flexion crease in the popliteal fossa This incision is used for exposure of the sciatic nerve at the point of division into tibial and common peroneal nerves. The incision is now carried transversely at the flexion crease in the popliteal fossa laterally to the border of the head of the fibula (Fig 98A Part 2) Now it is curved downwards lying between the bellies of the gastrocnemius and soleus muscles (Fig 98A Part 3) In this fashion the two flaps are retracted as shown in Fig 98C, and the tibial nerve may be followed into the calf while the peroneal nerve may be exposed on the lateral surface of the leg at the head of the fibula (Fig. 99) For exposure of the common peroneal nerve only the lower third of the incision alone may be used

CROSS SECTION OF POPLITEAL REGION

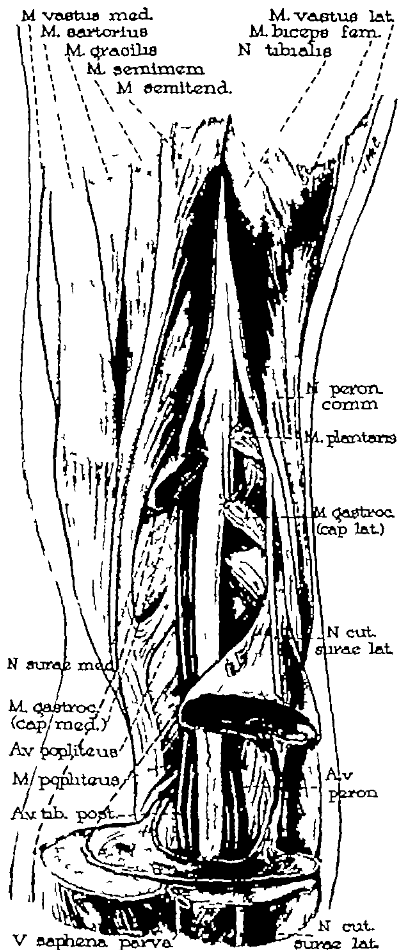
Surgical anatomy of the popliteal region (Fig 100)

SPECIAL PROCEDURES

Rongeuring of the sciatic notch (Fig. 101B) When the point of sciatic nerve injury extends into the pelvis a portion of the sciatic notch may be removed in order to gain access to the viable portion of sciatic nerve (Fig 101)



Figure 99 Operative exposure of the sciatic nerve and its divisions in the popliteal region showing author's Z incision.



M vastus med.
M. sartorius
M. gracilis
M. semimem
M semitend.
M. vastus lat.
M. biceps fem.
N tibialis
N peron. comm
M. plantaris
M gastroc. (cap lat.)
N cut. surae lat.
N surae med.
M. gastroc. (cap. med.)
Av popliteus
M popliteus
Av tib. post.
Av peron
V saphena parva
N cut. surae lat.

Figure 100.

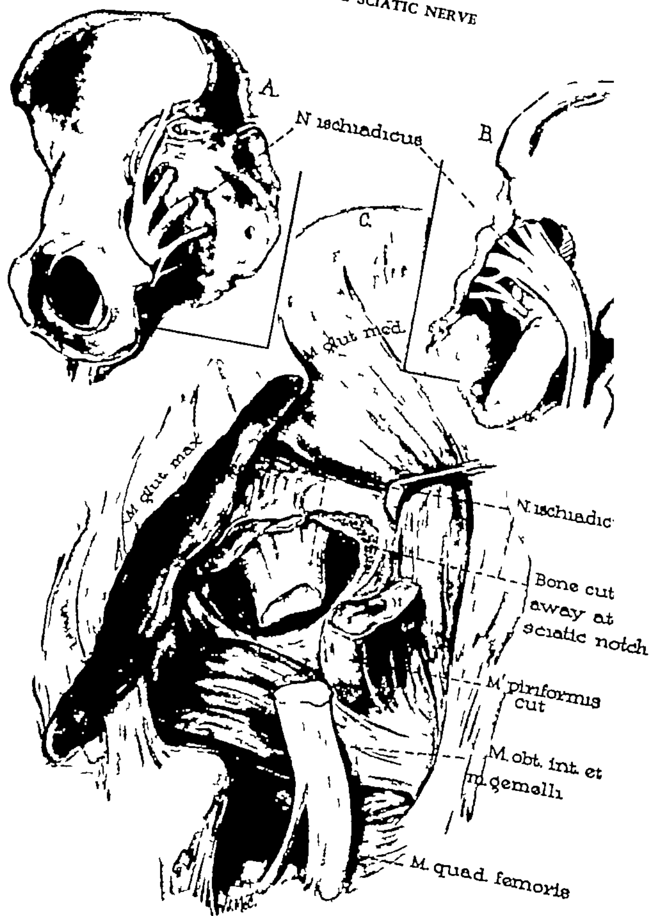

A
N ischiadicus
B
C
M glut med
M glut max
N ischiadic
Bone cut away at sciatic notch
M piriformis cut
M obt. int. et m gemelli
M quad. femoris

Figure 101

XVI

THE FOOT

Injury to the foot is considered more disabling than injury to the hand It immediately puts a man on crutches, if not in bed The pain element in foot injuries is as demoralizing as pain in the hand, and when the plantar surface of the foot is anesthetic trophic complications must lead to eventual amputation. While great strides have been achieved in clarifying the surgical anatomy and mechanics of the hand the attention given to similar injuries of the foot were found to still be inadequate This work on the foot was compiled during the study and repair of 901 nerve injuries to the leg and foot. Every procedure whether old or original, is presented only from the surgery of actual cases.

The radical re routing of the tibial nerve in the leg for repair of extensive gaps in the plantar nerves in the foot, is here presented for the first time

THE INTEROSSEI MUSCLES OF THE FOOT
(4 Dorsal—3 Plantar)

The interossei lie in the intervals between the metatarsal bones (intermetatarsal spaces)

DORSAL INTEROSSEI

(Fig 102C)

Origin

Two heads from either side of the metatarsals

Insertion

Dorsal aponeuroses of first phalanges—second third, and fourth toes.

Action

Flexion of first phalanges.
Extension of second and third phalanges.

Nerve

Tibial by lateral plantar branch.

PLANTAR INTEROSSEI

(Fig 102A)

Origin

By a single head from metatarsal bones (medial surface) of third, fourth, and fifth toes

Insertion

Aponeuroses of third, fourth, and fifth toes on the mesial side

Action

Flexion of first phalanges.
Extension of second and third phalanges.

Nerve

Tibial by lateral plantar branch.

LUMBRICALES MUSCLES

(Fig 102B)

Origin

Tendons of flexor digitorum longus in the manner shown in the diagram.

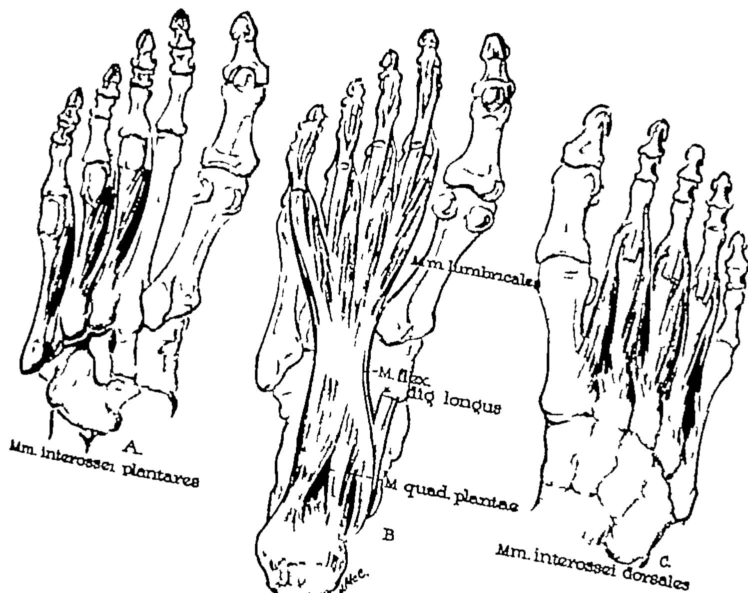

Mm. lumbricales
M. flex. dig. longus
M. quad. plantae
A.
Mm. interossei plantares
B
C.
Mm. interossei dorsales

Figure 102.

Insertion

Dorsal aponeuroses of second, third, fourth, and fifth toes.

Action

Flexion of first phalanges.

Nerve

Tibial — Lateral plantar for second, third, and fourth. Medial plantar for first.

THE DORSAL APONEUROSES OF THE TOES

The dorsal aponeuroses of the toes are essentially like those of the fingers They are formed by tendons of extensor brevis, extensor longus, the interossei, and lumbricales.

MUSCLES OF THE MEDIAL AN LATERAL PLANTAR REGIONS

Fig 103B shows the anatomy of the and lateral plantar group of muscles. muscles are comparable to the then hypothenar group of muscles of th (Fig 23A)

Origin

The flexors of the fifth and great tc a common origin in the region of tl plantar ligament, while the abduc the fifth toe and great toe have a co origin from the calcaneous (Fig 1(

Insertion

Shown in Fig 103A and 103B

Innervation

The lateral plantar group are suppl the lateral plantar nerve and the : plantar group by the medial plantar

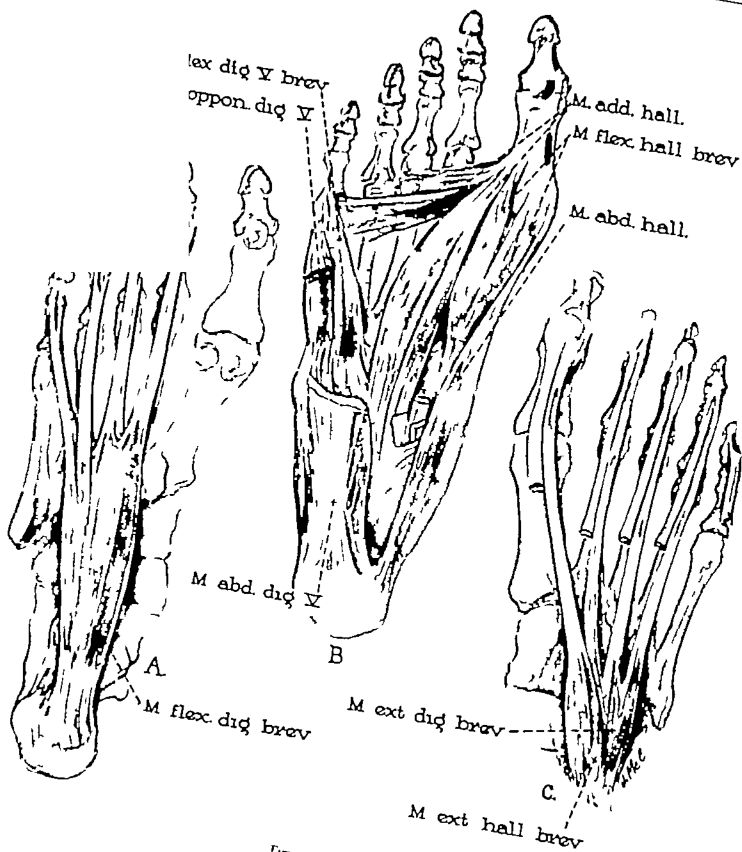

lex dig V brev
oppon. dig V
M. add. hall.
M flex. hall brev
M. abd. hall.
M abd. dig V
B
A
M flex. dig brev
M ext dig brev
C.
M ext hall brev

Figure 103

Insertion

Dorsal aponeuroses of second, third, fourth, and fifth toes.

Action

Flexion of first phalanges.

Nerve

Tibial } Lateral plantar for second third and fourth.
Medial plantar for first.

THE DORSAL APONEUROSES OF THE TOES

The dorsal aponeuroses of the toes are essentially like those of the fingers They are formed by tendons of extensor brevis, extensor longus, the interossei, and lumbricales

MUSCLES OF THE MEDIAL AND LATERAL PLANTAR REGIONS

Fig 103B shows the anatomy of the me and lateral plantar group of muscles. T muscles are comparable to the thenar hypothenar group of muscles of the h (Fig 23A)

Origin

The flexors of the fifth and great toe h a common origin in the region of the l plantar ligament, while the abductor the fifth toe and great toe have a com origin from the calcaneous (Fig. 103B

Insertion

Shown in Fig 103A and 103B

Innervation

The lateral plantar group are supplied the lateral plantar nerve and the me plantar group by the medial plantar ne

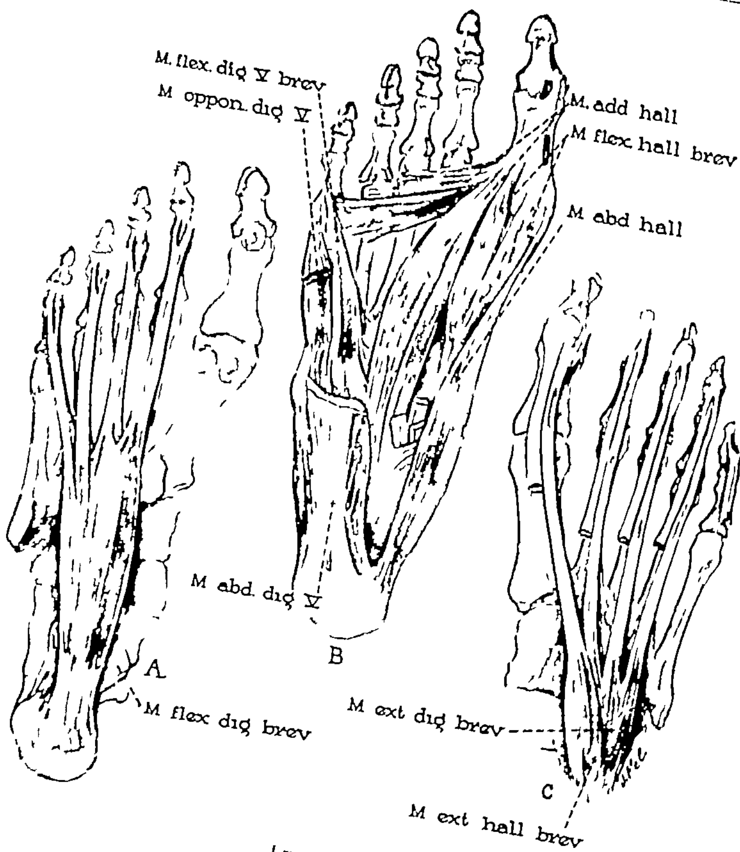

M. flex. dig V brev
M oppon. dig V
M. add hall
M flex. hall brev
M abd hall
M abd. dig V
A
B
M flex dig brev
M ext dig brev
C
M ext hall brev

Figure 3

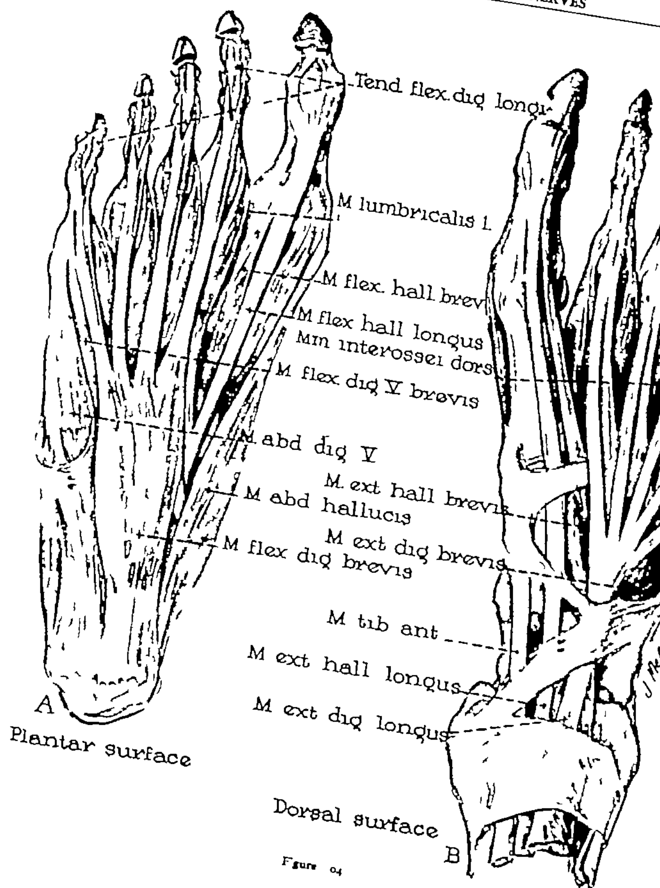

Tend flex dig longi
M lumbricalis 1.
M flex. hall brev
M flex hall longus
Mm interossei dors
M. flex dig V brevis
M. abd dig V
M. ext hall brevis
M abd hallucis
M ext dig brevis
M flex dig brevis
M tib ant
M ext hall longus
M ext dig longus
A
Plantar surface
Dorsal surface
B

Figure 94

A.

Dorsal extension of foot and toes. The following muscles abduct and pronate foot and extend toes

Nerve source – Peroneal nerve

Mm ext hall long et brev

Mm dig long and brev

M tib ant

Mm peronaei
tertius
longus
brev

B

Plantar flexion of foot and toes

Tibial nerve

M. flex hall long

M. flex dig long

M. tib post.

M gastrocnemius et

M soleus

M. plantaris

Peroneal nerve

Mm. peronaei long et brev

Plantar n. med and lat.

M. Flex. hall. brev

M lumbricales

M. Flex dig V brev

M oppon dig V

M. Flex dig brev

M. abd. dig V

Mm. interossei

M. quad plant.

M. abd hall

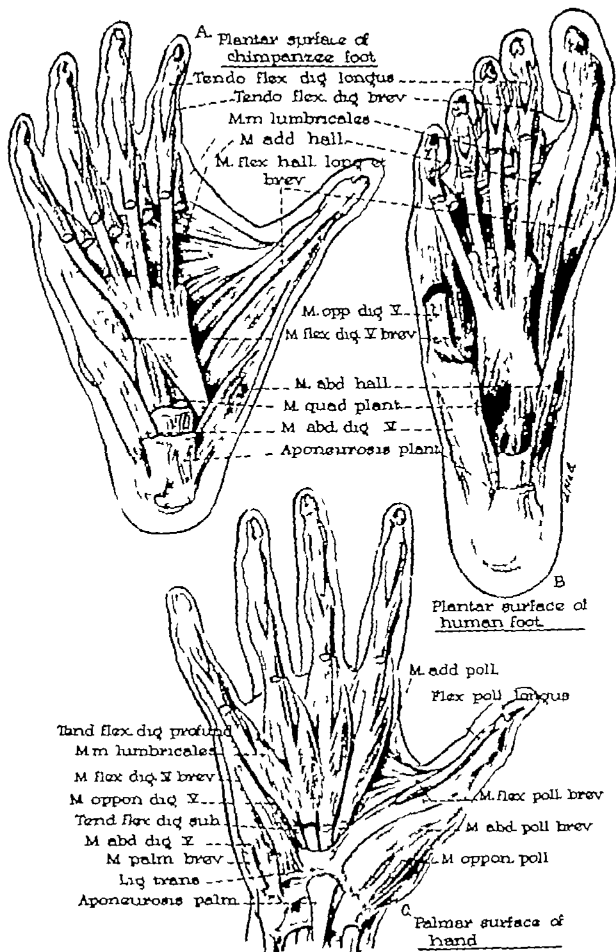

A. Plantar surface of chimpanzee foot
Tendo flex dig longus
Tendo flex. dig brev
Mm lumbricales
M add hall.
M. flex hall. long et brev
M. opp dig V
M flex dig V brev
M. abd hall.
M. quad plant.
M abd. dig V
Aponeurosis plant.
B
Plantar surface of human foot
M. add poll.
Flex poll longus
Tend flex. dig profund
Mm lumbricales
M flex dig V brev
M oppon dig V
Tend flex dig sub.
M abd dig V
M palm brev
Lig trans
Aponeurosis palm.
M. flex poll. brev
M abd. poll brev
M oppon. poll
C. Palmar surface of hand

Figure 104.

XVII

THE PERONEAL NERVE

The common peroneal nerve is the nerve for dorsiflexion (extension) of the foot Paralysis of this nerve gives foot drop The peroneal nerve in the foot is comparable to the radial nerve for the hand, paralysis of which gives wrist drop

ANATOMY

The common peroneal nerve is the lateral component of the sciatic nerve It is formed by fusion of the upper four posterior divisions of the sacral plexus and takes origin from L4, L5, S1, and S2 roots of the spinal cord. It descends obliquely in the popliteal fossa to the head of the fibula (Fig 107) Then, in between the tendons of the biceps femoris and lateral head of the gastrocnemius it passes over the neck of the fibula where it divides beneath the peroneus longus muscle into the three components deep peroneal superficial peroneal and recurrent articular of the knee joint. The deep peroneal nerve supplies the anterior tibial group of muscles, the superficial peroneal supplies cutaneous sensation to the lateral surface of the leg and dorsum of the foot and motor to the peroneal muscles (Fig 107)

COURSE AND DISTRIBUTION

a (Fig 107)
b Motor and Sensory Supply

Motor	Sensory	
common peroneal		articular to knee joint—lateral sural cutaneous of common peroneal joins the medial sural cutaneous of tibial to form sural which supplies the skin over dorsolateral leg and lateral side of foot
deep peroneal	tibialis anterior extensor digitorum longus extensor hollucis longus peroneus tertius extensor digitorum brevis	cutaneous to adjacent sides of first two toes
peroneal	peroneus longus peroneus brevis	lateral surface of leg and dorsum of foot and adjacent sides of two to five toes
recurrent articular		knee joint tibio-fibular joint

LEVEL OF LESION AND CHARACTERISTIC SYMPTOMS

Involvement of the main trunk of the common peroneal nerve gives loss of ability to dorsiflex the foot and proximal three phalanges which results in foot drop (Fig 108) A steppage gait results. The patient raises the knee high in order to lift the toes above the ground and 'slaps the foot down There is also a loss of ability to abduct or evert the foot (Figs. 109A and 110) and an atrophy of the tibial and peroneal muscles with anesthesia over the lateral surface of the leg and dorsum of the foot (Fig 111) Injury in the region of the ankle may produce loss of extension of the toes When the deep peroneal nerve is injured below the level of supply to extensors longus and tibialis anterior there is isolated paralysis of the extensor of the great toe (Fig 112) Sensory loss is shown in Fig 113 Partial lesions will give isolated paralysis of muscles involved. Paralysis of the superficial peroneal nerve gives paralysis of the peroneus longus and brevis muscles, with eversion of the foot on dorsiflexion (Fig 109B) The zone of anesthesia is shown in Fig. 114.

SURGICAL ANATOMY

(Fig 100)

INCISIONS FOR OPERATIVE EXPOSURE

Refer to the incisions in Fig. 98A This incision may be continued down the anterolateral surface of the leg for exposure of divisions of the peroneal nerve

CROSS SECTION

(Fig 98C)

SPECIAL PROCEDURES

By using the special Z incision in popliteal space and by freeing adequately the nerve a gap of ten to twelve centimeters may be overcome by flexing acutely the knee

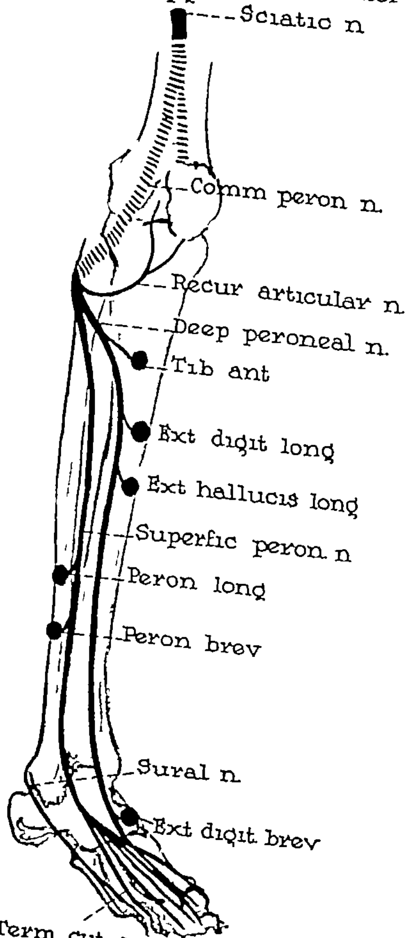

Common peroneal nerve
L4 5 S1-2
Sciatic n
Comm peron n.
Recur articular n
Deep peroneal n.
Tib ant
Ext digit long
Ext hallucis long
Superfic peron n
Peron long
Peron brev
Sural n.
Ext digit brev
Term cut rami to foot

Figure 107



Figure 108 Common peroneal nerve paralysis, showing foot drop effect.

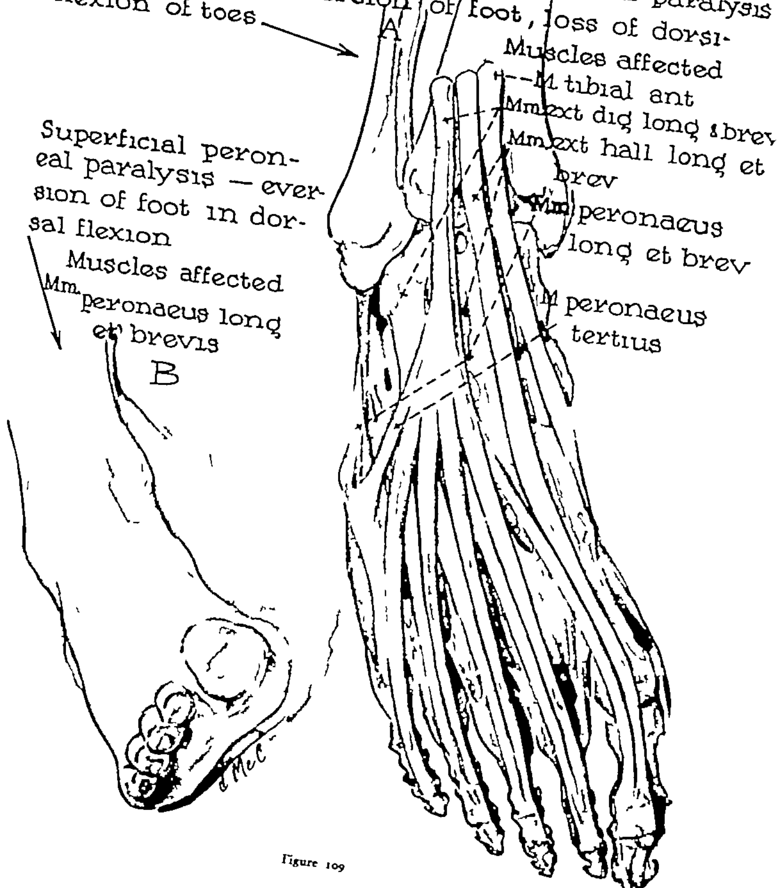

Appearance of foot affected by peroneal nerve paralysis Deep and superficial peroneal paralysis causes foot drop, eversion of foot, loss of dorsiflexion of toes
A
Muscles affected
M tibial ant
Mm ext dig long & brev
Mm ext hall long et brev
Mm peronaeus long et brev
M peronaeus tertius
Superficial peroneal paralysis — eversion of foot in dorsal flexion
Muscles affected
Mm peronaeus long et brevis
B

Figure 109



Figure 110. Common peroneal nerve paralysis in the right foot resulting in: (1) foot drop (2) eversion of foot; and (3) loss of ability to dorsiflex the toes The left foot is normal

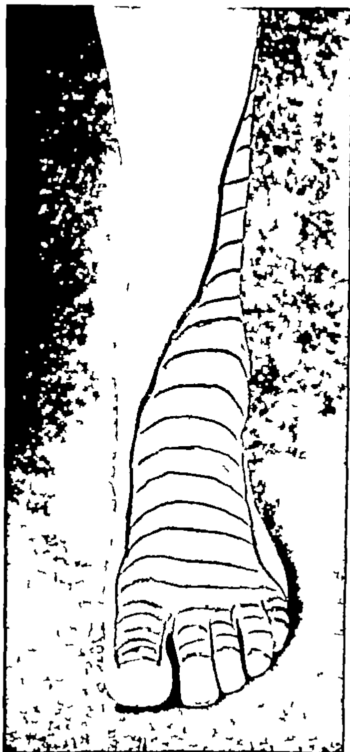


Figure 111 Common peroneal nerve paralysis showing sensory loss.

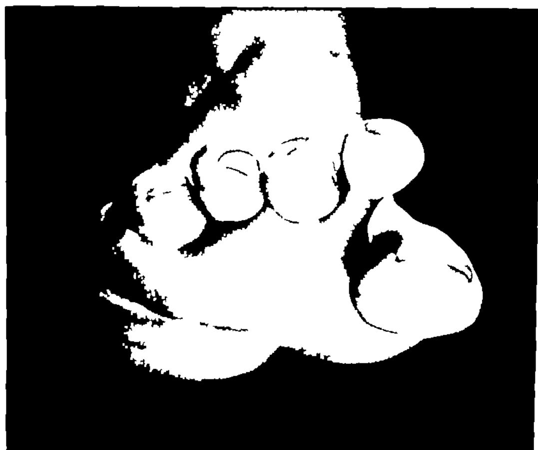


Figure 112. Deep peroneal nerve paralysis. The nerve injury is below the lev l of the supply to the extensor digitorum longus and tibialis anterior causing isolated paralysis of the extensor of the great toe.



Figure 113 Deep peroneal nerve paralysis showing sensory loss.

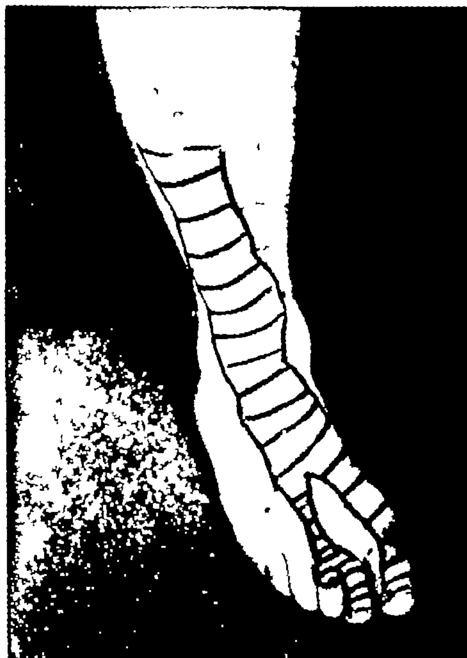


Figure 114. Superficial peroneal nerve paralysis, showing sensory loss.

XVIII

THE TIBIAL NERVE

The tibial nerve is the medial component of the sciatic nerve and is the most important nerve of the calf and foot It is comparable in importance and function to the foot as is the combined function of both the median and ulnar nerves to the hand The tibial nerve is by far the most important portion of the sciatic nerve inasmuch as it supplies all the calf muscles for walking and all the flexor muscles of the foot and toes for plantar flexion as well as sensation and tactile discrimination to the plantar surface of the foot.

The walk in tibial nerve paralysis is very much the same as that with an artificial limb and, in addition, trophic changes result with eventual ulcers that do not heal

The tibial nerve is the important nerve of the leg and foot in walking

ANATOMY

(Fig 115)

The tibial nerve is the medial component of the sciatic nerve It takes origin from the anterior divisions of the sacral plexus and roots of origin are from L4, L5, S1, S2, S3 roots of the spinal cord It descends along the back of the thigh and through the popliteal fossa to the lower portion of the popliteus muscle, where it enters beneath the arch of the soleus along with the popliteal artery It continues along the back of the leg with the posterior tibial vessels to the space just above the medial malleolus, where it divides into the medial and lateral plantar nerves The medial and lateral plantar nerves continue into the foot and supply all the small muscles

COURSE AND DISTRIBUTION

a. Diagram (Fig 116)

b *Motor and Sensory Supply*

	Motor	Sensory
Leg	gastrocnemius plantaris soleus popliteus *tibialis posterior* flexor digitorum longus (pedis) flexor hallucis longus	medial sural cutaneous of tibial and lateral sural cutaneous of the peroneal joint to form sural nerve *sural nerve* supplies cutaneous to dorsolateral part of leg and lateral side of foot
Medial plantar comparable to median nerve of hand	flexor digitorum brevis abductor hallucis first lumbricales	medial side of the sole medial three and one half toes—plantar surface
Lateral plantar comparable to ulnar nerve of hand	quadratus plantae abductor digiti quinti flexor digiti quinti brevis opponens digiti quinti abductors hallucis transverse and oblique 3 plantar interossei 4 dorsal interossei 3 lateral lumbricales	lateral portion of sole lateral one and one half plantar surface
Tibial nerve sensory loss is shown in Fig 117		

TESTS OF MUSCLE FUNCTION AND THE INTACTNESS OF THE TIBIAL NERVE

Nerve	Muscle	Test
tibial L5 S1 S2	flexor digitorum longus flexor hallucis longus	flex toes against resistance

LEVEL OF LESION AND CHARACTERISTIC SYMPTOMS

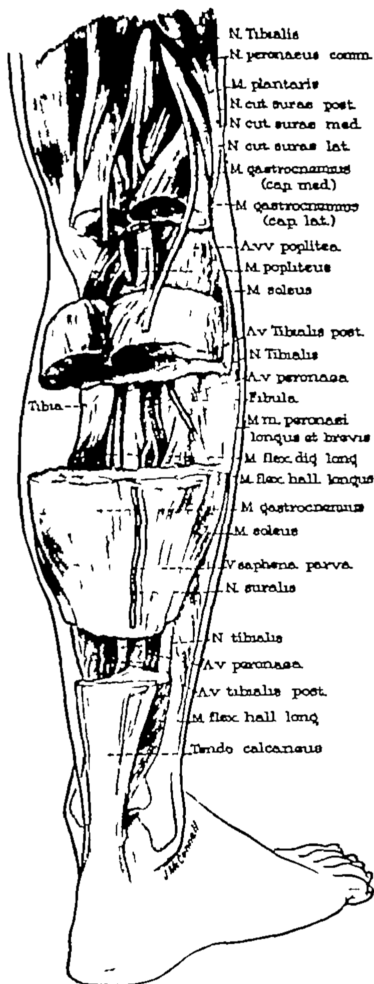
Injury of the main tibial trunk above the level of the popliteal region produces loss of ability to plantar flex adduct, or invert the foot (Fig 118) loss of ability to flex, abduct (separate) or adduct the toes. Loss of plantar flexion of toes (Fig 119) may eventually produce a claw foot (Fig. 120), and atrophy of the calf and foot muscles develop Vasomotor and trophic changes are frequent (Fig. 121) and pain (causalgia) is observed in some incomplete lesions.

Pathologic anatomy of tibial nerve paralysis is shown in Fig 122

Injury at the ankle involves only the medial and lateral plantar nerves with resultant paralysis of the toes, marked atrophy of plantar muscles, with hyperaction of dorsal extensors producing the appearance of pes cavus, complete anesthesia of the sole of the foot and plantar surface of toes (Fig 123)

SURGICAL ANATOMY

(Fig 115)


N. Tibialis
N. peronaeus comm.
M. plantaris
N. cut. surae post.
N. cut. surae med.
N. cut. surae lat.
M. gastrocnemius
(cap. med.)
M. gastrocnemius
(cap. lat.)
A.vv. poplitea.
M. popliteus
M. soleus
A.v. Tibialis post.
N. Tibialis
A.v. peronaea.
Fibula.
Tibia
Mm. peronaei
longus et brevis
M. flex. dig. long.
M. flex. hall. longus
M. gastrocnemius
M. soleus
V. saphena. parva.
N. suralis
N. tibialis
A.v. peronaea.
A.v. tibialis post.
M. flex. hall. long.
Tendo calcaneus

INCISIONS FOR OPERATIVE EXPOSURE

A review of the anatomy of the leg reveals that the tibial nerve lies beneath the calf muscles, the gastrocnemius and soleus, and adjacent to the posterior tibial muscle The best surgical approach is by a longitudinal incision over the mesial surface of the leg and approached beneath the fascial plane of the soleus muscle[1] (Fig 124A) This incision may be continued proximally when it is necessary to reflect the soleus muscle in the presence of a very extensive tibial nerve defect. The tibial nerve must never be approached through the calf by a posterior incision since the muscles are so constructed that they cannot be split in the direction of their fibers. The trauma produced by penetrating the calf muscles results in severe post operative reaction as well as in severely disabling adhesions between the calf muscles It definitely impedes plantar flexion of the foot.

SURGICAL EXPLORATION

(*Fig 124C*)

CROSS SECTION OF THE CALF

(*Fig 124B*) shows anatomic relationship of the tibial nerve and also the surgical approach.

SPECIAL PROCEDURES

Re-routing of the tibial nerve is necessary for overcoming extensive gaps (Fig. 125) It is possible to overcome a gap of fifteen centimeters in the tibial nerve by a careful and radical re routing The longitudinal incision along the middle third of the leg on its mesial surface is continued upward along the border of the soleus muscle into the popliteal region. The attachment of the soleus muscle is severed and the tibial nerve exposed. By carefully freeing the nerve, and stripping the motor twigs to the gastrocnemius, popliteus, plantaris, and soleus muscles, the nerve may be removed from the popliteal space, and, with the knee in acute flexion twelve to fifteen centimeters may be obtained Repair of medial and lateral plantar nerves with extensive gap, may be performed after a re-routing of the tibial nerve in the leg (Fig 126)

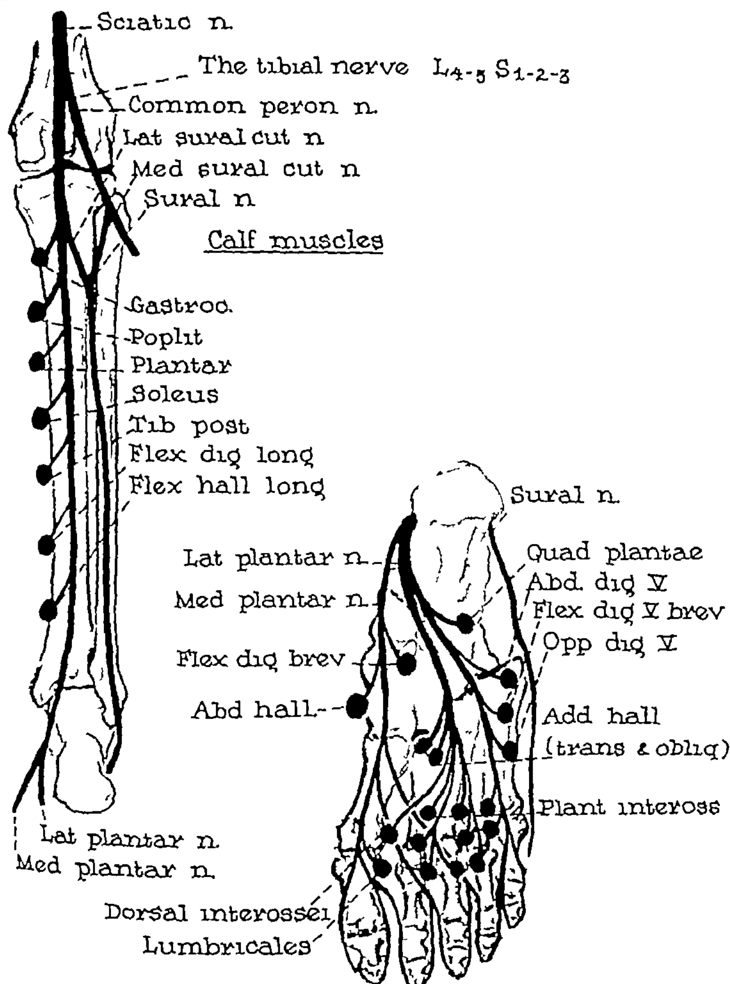


Figure 116 (Modified after McDonald Green and Lange *CORRELATIVE NEUROANATOMY*)



Figure 117 Sensory loss in tibial nerve paralysis. The healed wound over the medial surface of the leg is clearly noted.



Figure 118 Tibial nerve paralysis, resulting in the loss of plantar flexion of the foot and ankle atrophy of the calf muscles, and a sensory loss



Figure 121 Trophic ulcer in tibial nerve paralysis.


Loss of tibial nerve
Inability to flex foot or toes plantarward or evert foot
A
All plantar muscles affected except m.m peronaeus longus et brevis


Loss of med plantar n
Big toe adducted
Muscles affected
B
M. lumbricalis 1
M flex hall brev
M. abd hallucis
M flex dig brev

Figure 122



Figure 123 Medial and lateral plantar nerve paralysis producing (1) marked atrophy of the plantar muscles; (2) loss of plantar flexion of all toes and (3) hyperaction of the dorsal extensors producing the appearance of a high arch (pes cavis)

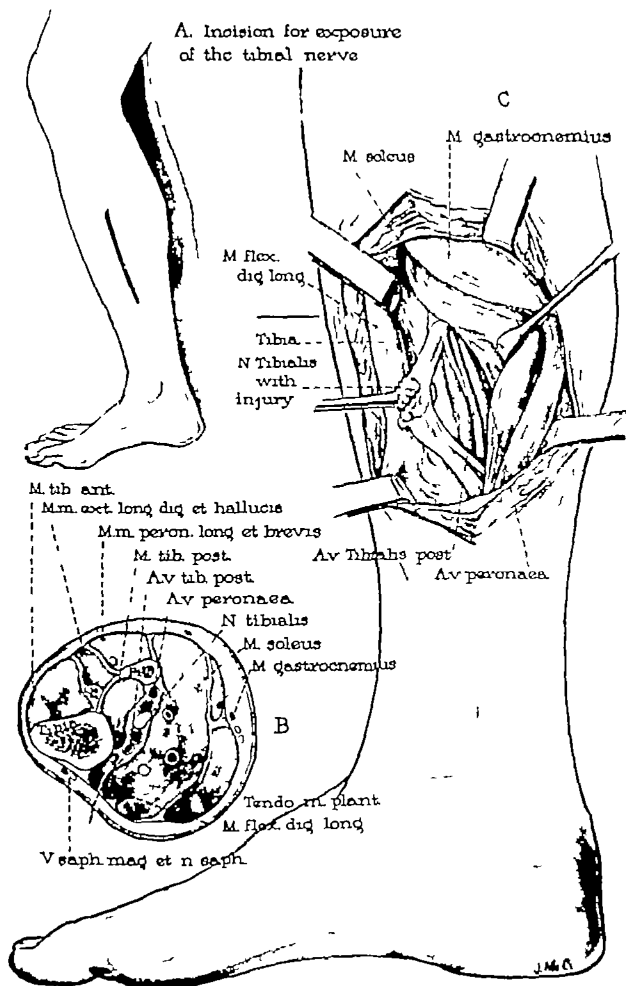

A. Incision for exposure of the tibial nerve
C
M gastrocnemius
M soleus
M flex. dig long
Tibia
N Tibialis with injury
M. tib ant.
Mm. ext. long dig et hallucis
Mm. peron. long et brevis
M. tib. post.
A.v tib. post.
A.v peronaea
N tibialis
M. soleus
M gastrocnemius
B
Tibia
Tendo m. plant.
M. flex. dig long
V saph. mag et n saph.
A.v Tibialis post
A.v peronaea
J.McG.

Figure 124.

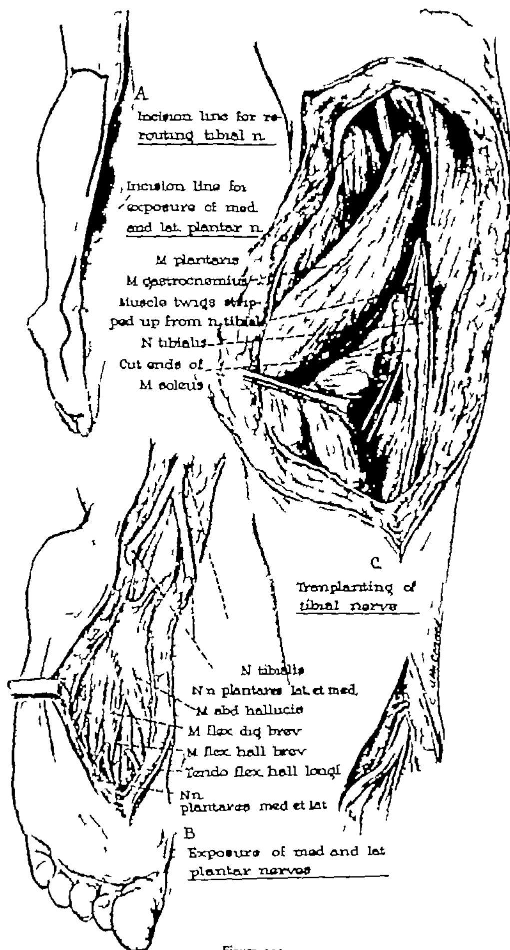
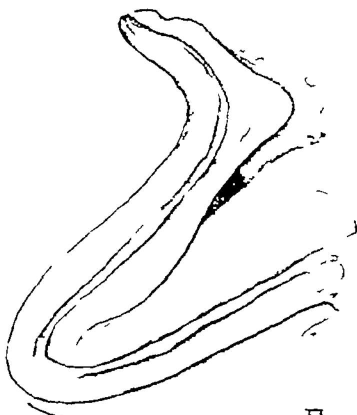

A
Incision line for rerouting tibial n.
Incision line for exposure of med. and lat. plantar n.
M plantaris
M gastrocnemius
Muscle twigs stripped up from n. tibialis
N tibialis
Cut ends of M soleus
C
Transplanting of tibial nerve
N tibialis
N n plantares lat. et med.
M abd hallucis
M flex dig brev
M flex. hall brev
Tendo flex. hall longi
Nn. plantares med et lat
B
Exposure of med and lat plantar nerves

Figure 125

D

Nn plantares med et lat sutured to nn dig plant comm and nn plant lat (ramus sup)



Position of leg in cast after repair of nerve

Figure 125 (continued)

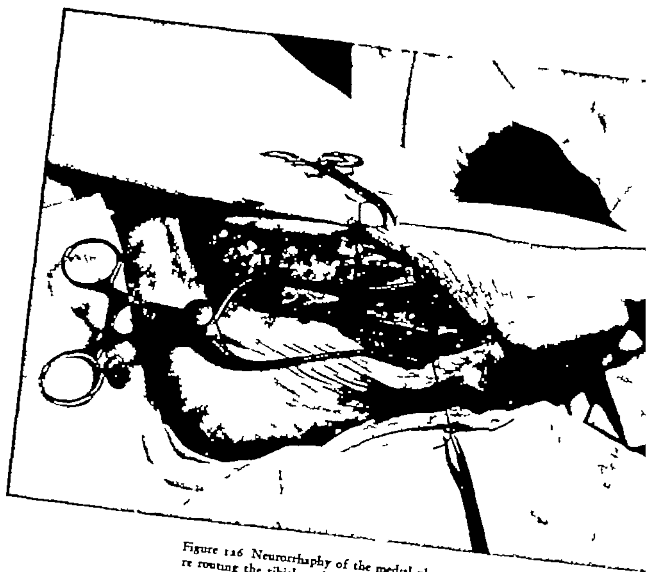


Figure 126 Neurorrhaphy of the medial plantar nerve after re routing the tibial in the leg as shown in Figure 125D

XIX

INJURIES TO THE CRANIAL NERVES

The cranial nerves most frequently injured are the facial (VII), spinal accessory (XI), the hypoglossal (XII), and the recurrent-laryngeal of the vagus.

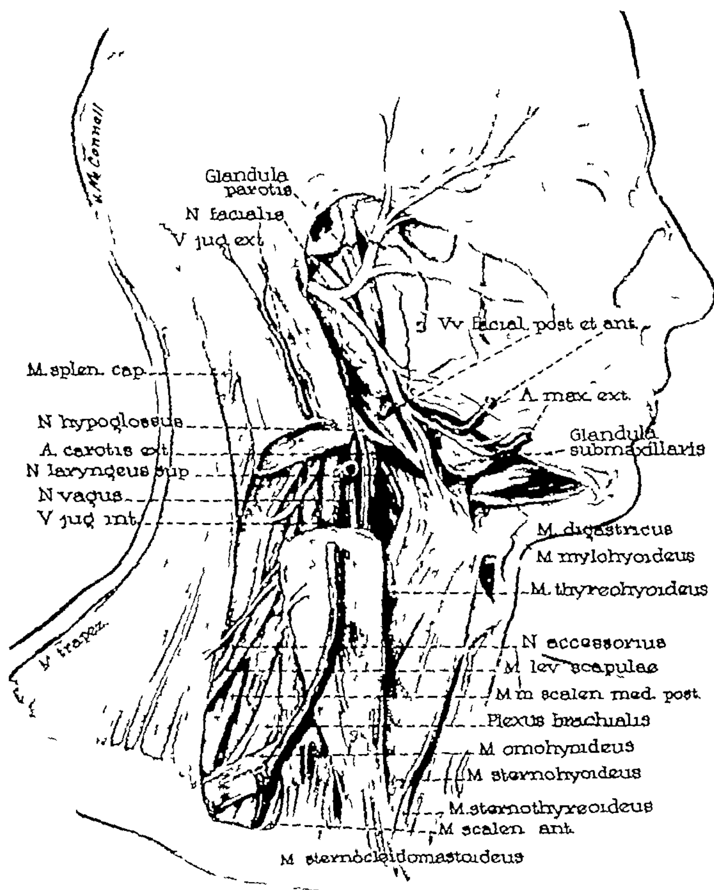
Paralysis of the facial nerve results in complete facial paralysis Fig 127 shows the anatomy of the neck and facial nerve Fig 128 shows the incision and exposure of the facial nerve

Paralysis of the spinal accessory nerve produces atrophy and paralysis of the trapezius muscle and shoulder drop (Figs. 129, 130)

Paralysis of the hypoglossal nerve results in atrophy and deviation of the tongue (Figs. 131 and 132)

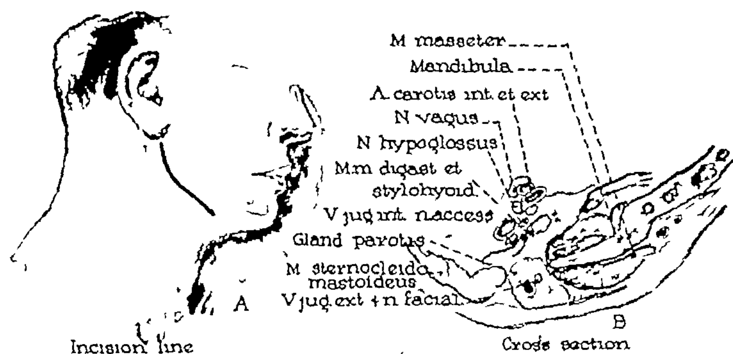
Paralysis of the recurrent laryngeal or vagus nerve produces paralysis of the vocal cord with hoarseness and difficulty in swallowing

Figs 133 and 134 show incision and exposure of the vagus hypoglossal spinal accessory, and recurrent laryngeal nerves.



K McConnell
Glandula parotis
N facialis
V jug ext
Vv facial post et ant
M splen cap
A max ext
N hypoglossus
Glandula submaxillaris
A carotis ext
N laryngeus sup
N vagus
V jug int
M digastricus
M mylohyoideus
M thyreohyoideus
M trapez
N accessorius
M lev scapulae
M m scalen med post
Plexus brachialis
M omohyoideus
M sternohyoideus
M sternothyreoideus
M scalen ant
M sternocleidomastoideus

Figure 127


M masseter
Mandibula
A carotis int et ext
N vagus
N hypoglossus
Mm digast et stylohyoid
V jug int n access
Gland parotis
M sternocleido mastoideus
V jug ext + n facial
A
Incision line
B
Cross section

N facialis
Glandula parotis
Platysma
C
Exposure of facial n.

Figure 118



Figure 129 Spinal accessory nerve paralysis with trapezius atrophy and shoulder drop

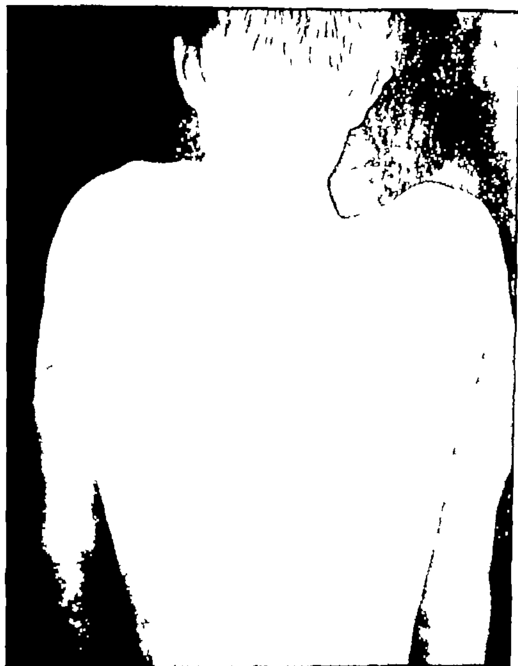


Figure 130. Spinal accessory nerve paralysis. The patient is attempting to shrug his shoulders



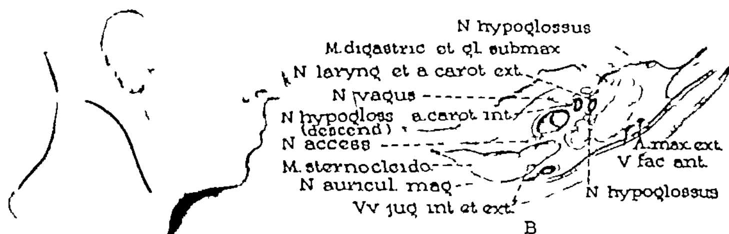
Figure 131 Twelfth cranial (hypoglossal) nerve paralysis in a neck injury with hemiatrophy of the tongue



Figure 132 Hypoglossal nerve injury with deviation of the tongue.



Figure 135 A healed incision in a flexion crease for the exposure of the hypoglossal nerve in the neck.



A.
Incision line in flexion crease.

V jug int.
N accessorius
M masseter
N vagus
A. carotis ext.
N hypoglossus
Glandula submaxillaris
N. laryngeus
V jug ext.
M sternocleidomastoid
C

Figure 134

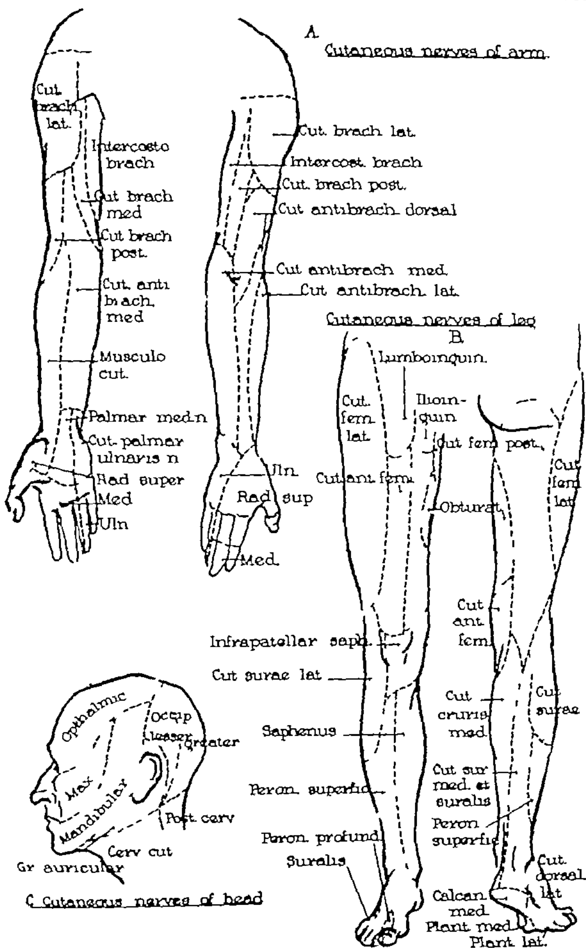
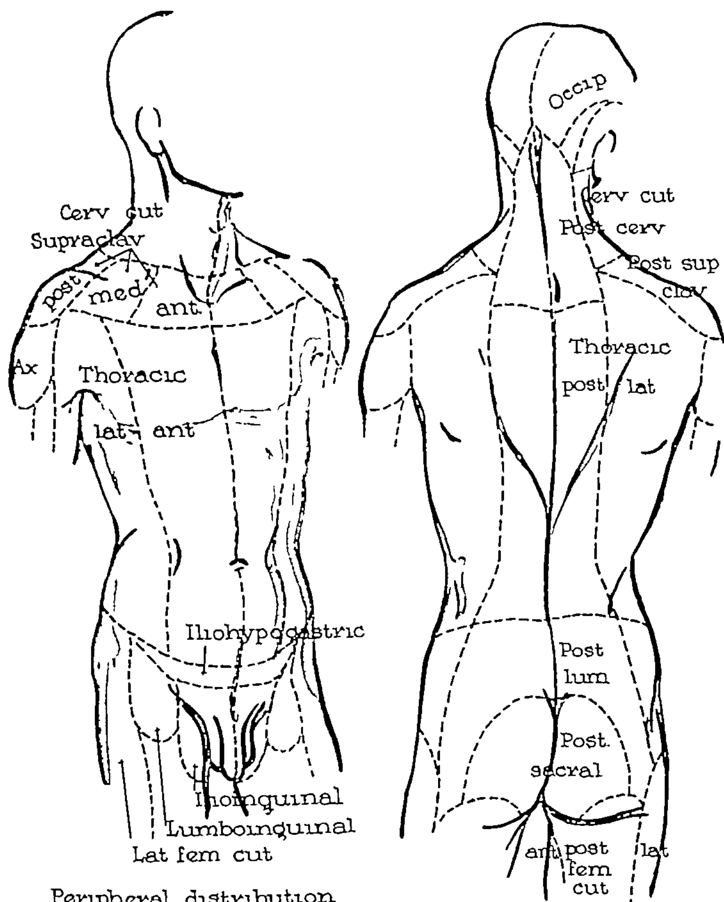

A
Cutaneous nerves of arm.
Cut. brach lat.
Intercosto brach
Cut brach med
Cut brach post.
Cut. anti brach. med
Musculo cut.
Palmar med.n
Cut. palmar ulnaris n
Rad super
Med
Uln
Cut. brach lat.
Intercost. brach
Cut. brach post.
Cut antibrach. dorsal
Cut antibrach med.
Cut antibrach. lat.
Uln.
Rad sup
Med.
Cutaneous nerves of leg
B.
Lumboinquin.
Cut. fem. lat.
Ilioin-guin
Cut fem post.
Cut ant. fem.
Obturat
Cut fem lat
Cut ant. fem.
Infrapatellar saph.
Cut surae lat
Cut cruris med.
Cut surae
Saphenus
Cut sur med. et suralis
Peron. superfic
Peron superfic
Peron. profund
Suralis
Cut. dorsal lat
Calcan. med.
Plant. med
Plant. lat.
Opthalmic
Occip lesser
greater
Max
Mandibular
Post. cerv
Cerv cut
Gr auricular
C Cutaneous nerves of head

Figure 135



Peripheral distribution

INDEX

THIS BOOK

SURGERY
of
PERIPHERAL NERVES

By

EMIL SELETZ, M D

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